Notes on the Troubleshooting and Repair of Microwave Ovens

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Preface

Author and Copyright

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DISCLAIMER

Careless troubleshooting of a microwave oven can result in death or worse. Experienced technicians have met their maker as a result of a momentary lapse of judgement while testing an oven with the cover removed. Microwave ovens are without a doubt, the most deadly type of consumer electronic equipment in wide spread use.

The power supplies for even the smallest microwave ovens operate at extremely lethal voltage and current levels. Do not attempt to troubleshoot, repair, or modify such equipment without understanding and following ALL of the relevant safety guidelines for high voltage and/or line connected electrical and electronic systems.

We will not be responsible for damage to equipment, your ego, county wide power outages, spontaneously generated mini (or larger) black holes, planetary disruptions, or personal injury or worse that may result from the use of this material.

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Introduction

Radar Range anyone?

Remember when you actually had to use the real oven to defrost a TV dinner? Think back - way back - before VCRs, before PCs (and yes, before Apple computers as well), almost before dinosaurs, it would seem. There was a time when the term 'nuke' was not used for anything other than bombs and power reactors.

For a long time, there was controversy as to whether microwave ovens were safe - in terms of microwave emissions and molecular damage to the food. Whether these issues have been resolved or just brushed aside is not totally clear. Nonetheless, the microwave oven has taken its place in virtually every kitchen on the planet. Connoisseurs of fine dining will turn up their collective noses at the thought of using a microwave oven for much beyond boiling water - if that. However, it is difficult to deny the convenience and cooking speed that is provided by this relatively simple appliance.

Microwave ovens are extremely reliable devices. There is a good chance that your oven will operate for 10 years or more without requiring repairs of any kind - and at performance levels indistinguishable from when it was first taken out of the box. Unlike other consumer electronics where a new model is introduced every 20 minutes - some even have useful improvements - the microwave oven has not changed substantially in the last 20 years. Cooking is cooking. Touchpads are now nearly universal because they are cheaper to manufacture than mechanical timers (and also more convenient). However, an old microwave oven will heat foods just as well as a brand new one.

This document provides maintenance and repair information applicable to most of the microwave ovens in existence. It will enable you to quickly determine the likely cause and estimate the cost of parts. You will be able to make an informed decision as to whether a new oven is the better alternative. With minor exceptions, specific manufacturers and models will not be covered as there are so many variations that such a treatment would require a huge and very detailed text. Rather, the most common problems will be addressed and enough basic principles of operation will be provided to enable you to narrow the problem down and likely determine a course of action for repair. In many cases, you will be able to do what is required for a fraction of the cost that would be charged by a repair center - or - be able to revive something that would otherwise have gone into the dumpster or continued in its present occupation as a door stop or foot rest.

Should you still not be able to find a solution, you will have learned a great deal and be able to ask appropriate questions and supply relevant information if you decide to post to sci.electronics.repair. In any case, you will have the satisfaction of knowing you did as much as you could before taking it in for professional repair. You will be able to decide if it is worth the cost of a repair as well. With your new-found knowledge, you will have the upper hand and will not easily be snowed by a dishonest or incompetent technician.

On-line microwave oven repair database

Microtech maintains a web site with a large amount of information on microwave oven repair including an on-line Tech Tips Database with hundreds of solutions to common problem for many models of microwave ovens. There are also an extensive list of microwave oven related links to other interesting sites (including this document!). The comprehensive Safety Info is a must read as well. Not entirely coincidentally, I assume, some of its wording appears remarkably familiar! Microtech also offers instructional videos and books on microwave oven and VCR repair.

It is quite possible your problem is already covered at the Microtech site. In that case, you can greatly simplify your troubleshooting or at least confirm a diagnosis before ordering parts. My only reservation with respect to tech tips databases in general - this has nothing to do with Microtech in particular - is that symptoms can sometimes be deceiving and a solution that works in one instance may not apply to your specific problem. Therefore, an understanding of the hows and whys of the equipment along with some good old fashioned testing is highly desirable to minimize the risk of replacing parts that turn out not to be bad.

The simplest problems

- Bad interlocks switches or door misalignment causing fuses to blow or no operation when the start button is pressed. Locate and replace defective switches and/or realign door.
- Arcing in oven chamber: clean oven chamber and waveguide thoroughly. Replace carbonized or damaged waveguide cover. Smooth rough metal edges. Touch up the interior paint.
- Blown fuse due to power surge or old age: Replace fuse. On rare occasions, the main fuse may even be intermittent causing very strange symptoms.
- An MOV, probably on the controller, may have shorted due to a power surge blowing the controller fuse. Remove remains of MOV, replace fuse and test, replace MOV for future surge protection.
- Erratic touchpad operation due to spill - let touchpad dry out for a week.
- Bugs in the works - the controller circuit board is a nice warm safe cozy place to raise a family.....

More detailed explanations are provided elsewhere in this document.

Repair or replace?

With small to medium size microwave ovens going for $60-100 it hardly makes sense to spend $60 to have one repaired. Even full size microwave ovens with full featured touchpanel can be had for under $200. Thus, replacement should be considered seriously before sinking a large investment into an older oven.

However, if you can do the repair yourself, the equation changes dramatically as your parts costs will be 1/2 to 1/4 of what a professional will charge and of course your time is free. The educational aspects may also be appealing. You will learn a lot in the process. Many problems can be solved quickly and inexpensively. Fixing an old microwave for the dorm room may just make sense after all.

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Installation and Preventive Maintenance

Microwave oven installation and use

To assure safety and convenient, follow these recommendations:

- Read your users manual from cover to cover especially if this is your first microwave. What a concept! If nothing else, you may discover that your oven has features you were not aware were even possible. In any case, there may be requirements or suggestions that are specific to your model and will enable you to get the most performance from your new microwave.
- Select a stand-alone unit rather than a built-in if possible. It will be cheaper to buy, cheaper and easier to service, and possibly more reliable since ventilation and adjacent heat producing appliances will not be as much of a factor.
- Select a convenient location - easy access and not too high or too low. This is particularly important if the door of the oven opens down instead of to the left side (only a few models are built this way, however).
- Put the microwave oven on its own dedicated 3 wire grounded circuit. Temporary use of a 3 to 2 prong adapter is acceptable only if the outlet box is properly grounded to begin with (BX, Romex, or conduit with ground) AND the adapter's ground wire or terminal is securely attached to the outlet box ground screw.

  Make sure the outlet is in good condition in either case. Check that the plug (or adapter) fits tightly and that there is no appreciable heating of the outlet during use of the microwave oven. If there is, spread the metal strips of each of the prongs apart if possible and/or replace the outlet.

A grounded outlet is essential for safety. Microwave ovens are high power devices and a separate circuit will eliminate nuisance fuse blowing or circuit breaker tripping when multiple appliances are being used at the same time. It will also minimize the possibility of Radio Frequency Interference (RFI) between it and any electronic equipment which might be on the same circuit. A GFCI is not needed as long as the outlet is properly grounded and may result in nuisance tripping with some microwave ovens.

Inexpensice outlet testers are available at hardware stores, home centers, and electrical parts distributors, to confirm that the outlet is properly wired and grounded.

- Allow adequate ventilation - do not push it up against the wall or wedge it under a tight fitting wall cabinet (or inside one for that matter!). Leave at least 2 inches on all sides and top if possible.
- Do not let children use the microwave oven unless properly supervised. It is very easy to cause a fire through the use of excessive times or power settings. Even something as simple as microwave popcorn can explode and/or catch fire if heated for too long - e.g., 5 minutes instead of my precisely determined 3:41 on high :-).

Microwave oven maintenance

Most people do not do anything to maintain a microwave oven. Many will go for 20 years or more without any noticeable decline in performance. While not much preventive maintenance is needed, regular cleaning at least will avoid potentially expensive repairs in the future. Most of this involves things that don't require going inside and anyone can do. A shop that wants to add on preventive maintenance while doing some other repair is just trying to pad their wallet - anything that was required to ensure the health of the oven should have been included. :)

- Clean the interior of the oven chamber after use with a damp cloth and some detergent if necessary. Built up food deposits can eventually carbonize resulting in sparks, arcs, heating, and damage to the mica waveguide cover and interior paint - as well as potentially more serious damage to the magnetron. If there is any chance of food deposits having made their way above the waveguide cover in the roof of the chamber, remove the waveguide cover and thoroughly clean inside the waveguide as well.
- Clean the exterior of the cabinet and touchpad in a similar manner. DO NOT use a spray where any can find its way inside through the door latch or ventilation holes, or a dripping wet cloth. Be especially careful around the area of the touchpad since liquid can seep underneath resulting in unresponsive or stuck buttons or erratic operation. Do not use strong solvents (though a bit of isopropyl alcohol is fine if needed to remove sticky residue from unwanted labels, for example).
- Inspect the cord and plug for physical damage and to make sure the plug is secure and tight in the outlet - particularly if the unit is installed inside a cabinet. (Yes, I know it is difficult to get at but I warned you about that!.) Heat, especially from a combination microwave/convection oven or from other heat producing appliances can damage the plug and/or cord. If there is evidence of overheating at the outlet itself, the outlet (and possibly the plug as well) should be replaced.
- Periodically check for built up dust and dirt around the ventilation holes or grills. Clean them up and use a vacuum cleaner to suck up loose dust. Keeping the ventilation free will minimize the chance of overheating.
- Listen for any unusual sounds coming from inside the oven. While these appliances are not exactly quiet, grinding, squealing, scraping, or other noises - especially if they were not there when the oven was new - may indicate the need for some more extensive maintenance like belt replacement or motor lubrication. Attending to these minor problems now may prevent major repairs in the future.
- Keep your kitchen clean. Yes, I know, this isn't exactly microwave specific but cockroaches and other uninvited guests might just like to take up residence inside the electronics bay of the oven on the nice warm controller circuit board or its neighborhood and they aren't generally the tidiest folks in the world.

  If it is too late and you have a recurring problem of cockroaches getting inside the electronics bay, tell them to get lost and then put window screen over the vents (or wherever they are entering). Such an open mesh should not affect the cooling of the electronic components significantly. However, the mesh will likely clog up more quickly than the original louvers so make sure it is cleaned regularly. If possible, clean up whatever is attracting the unwanted tenants (and anything they may have left behind including their eggs!!). WARNING: See the section: SAFETY before going inside.

CAUTION: Do not spray anything into the holes where the door latch is inserted or anywhere around the touchpad as this can result in internal short circuits and costly damage - or anywhere else inside, for that matter. If you do this by accident, immediately unplug the oven and let it dry out for a day or two.

How long does microwave energy hang around?

You have probably been warned by your mother: "Wait a few seconds (or minutes) after the beep for all the microwaves to disappear". There is no scientific basis for such a recommendation. Once the beep has sounded (or the door has opened), it is safe. This is because:

1. There is no such thing as residual microwave radiation from a microwave oven - it is either being produced or is non-existent.
2. There is little energy storage in the microwave generator compared to the amount being used. The typical high voltage capacitor - the only component that can store energy - has a capacity of less than 15 W-s (Watt-seconds) even for the largest ovens. Power consumption is typically 800 to 1,500 W depending on oven size. Therefore, the capacitor will be fully drained in much less than .1 second - long before the beep has ended or the door has cleared the front panel. (Based on the numbers, above, for a 1,500 W oven with a capacitor storing 15 W-s, it is more like .01 seconds!)

   WARNING: This only applies to a *working* microwave oven! If there is no heat, the magnetron may not be drawing any current from the HV power supply and the HV capacitor can remain charged for a long time. In this case, there is a very real risk of potentially lethal electrical shock even after several minutes or more of being unplugged! See the section: SAFETY if you will be troubleshooting a microwave oven.

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Microwave Oven Troubleshooting

SAFETY

The following applies to microwave oven troubleshooting - once the cabinet cover is removed. There is also safety information on proper use of the oven in subsequent sections, below.

Please see Typical Microwave Oven Electronics Bay for parts identification.

WARNING! WARNING! WARNING! WARNING! WARNING! WARNING! WARNING! WARNING!

Microwave ovens are probably the most dangerous of consumer appliances to service. Very high voltages (up to 5000 V) at potentially very high currents (AMPs) are present when operating - deadly combination. These dangers do not go away even when unplugged as there is an energy storage device - a high voltage capacitor - that can retain a dangerous charge for a long time. If you have the slightest doubts about your knowledge and abilities to deal with these hazards, replace the oven or have it professionally repaired.

Careless troubleshooting of a microwave oven can not only can fry you from high voltages at relatively high currents but can microwave irradiate you as well. When you remove the metal cover of the microwave oven you expose yourself to dangerous - potentially lethal - electrical connections. You may also be exposed to potentially harmful levels of microwave emissions if you run the oven with the cover off and there is damage or misalignment to the waveguide to the oven chamber.

There is a high voltage capacitor in the microwave generator. Always ensure that it is totally discharged before even thinking about touching or probing anything in the high voltage power circuits. See the troubleshooting sections later in this document.

To prevent the possibility of extremely dangerous electric shock, unplug the oven from the AC outlet before removing the cover and do not plug it in to operate it with the cover off if at all possible. If you must probe live, remove the connections to the magnetron (see below) to prevent the inadvertent generation of microwaves except when this is absolutely needed during troubleshooting. Discharge the high voltage capacitor (with the oven unplugged) and then use clip leads to make any connections before you plug it in and apply power. Then after removing power and unplugging the oven discharge the HV capacitor once again.

WARNING: Experienced technicians have been electrocuted deader than a brick from even careful probing of the HV circuits of a powered microwave oven. Therefore, I highly recommend avoiding any probing of the HV circuits - nearly everything can be determined by inspection and component tests with the oven unplugged.

The microwave oven circuitry is especially hazardous because the return for the high voltage is the chassis - it is not isolated. In addition, the HV may exceed 5000 V peak with a continuous current rating of over .25 AMP at 50/60 Hz - the continuous power rating of the HV transformer may exceed 1,500 W with short term availability of much greater power. Always observe high voltage protocol.

There are two additionals non-electrical safety concerns that are *probably* not present in consumer microwave ovens but still need to be mentioned:

- There is a very slight chance that the antenna insulator at the top of the magnetron is made of Beryllium Oxide (BeO), which an extremely toxic material in dust or powder form. (Solid BeO is not particularly hazardous.) A ceramic made of BeO is an excellent heat conductor and for this reason may be present in the insulating parts of radar magnetrons as well as high power laser tubes and the like. If BeO is present, there should be at least one prominent warning label. However, there is always the possibility of a really old microwave oven having a magnetron containing BeO with no warning label or where it fell off. So, it is good practice to NOT attempt to break, smash, grind, pulverize, or otherwise attack the ceramic insulator on the top of the magnetron.
- The high voltage capacitors in really old microwave ovens may have been filled with PCBs (PolyChloroBenzenes) which have been banned in 1979 for being carcinogenic. It's unlikely these would leak. Just don't chop them open!

Safety guidelines

These guidelines are to protect you from potentially deadly electrical shock hazards as well as the equipment from accidental damage.

Note that the danger to you is not only in your body providing a conducting path, particularly through your heart. Any involuntary muscle contractions caused by a shock, while perhaps harmless in themselves, may cause collateral damage - there are many sharp edges inside this type of equipment as well as other electrically live parts you may contact accidentally.

The purpose of this set of guidelines is not to frighten you but rather to make you aware of the appropriate precautions. Repair of TVs, monitors, microwave ovens, and other consumer and industrial equipment can be both rewarding and economical. Just be sure that it is also safe!

- Don't work alone - in the event of an emergency another person's presence may be essential.
- Always keep one hand in your pocket when anywhere around a powered line-connected or high voltage system.
- Wear rubber bottom shoes or sneakers.
- Don't wear any jewelry or other articles that could accidentally contact circuitry and conduct current, or get caught in moving parts.
- Set up your work area away from possible grounds that you may accidentally contact.
- Know your equipment: TVs and monitors may use parts of the metal chassis as ground return yet the chassis may be electrically live with respect to the earth ground of the AC line. Microwave ovens use the chassis as ground return for the high voltage. In addition, do not assume that the chassis is a suitable ground for your test equipment!
- If circuit boards need to be removed from their mountings, put insulating material between the boards and anything they may short to. Hold them in place with string or electrical tape. Prop them up with insulation sticks - plastic or wood.
- If you need to probe, solder, or otherwise touch circuits with power off, discharge (across) large power supply filter capacitors with a 25 W or greater resistor of

5 to 50 ohms/V approximate value.

For the microwave oven in particular, use a 25K to 100K resistor rated for at least 5 kV and several watts with a secure clip lead to the chassis. Mount the resistor on the end of a well insulated stick. Touch each of the capacitor terminals to the non-grounded end of the resistor for several seconds. Then, to be doubly sure that the capacitor if fully discharged, short across its terminals with the blade of a well insulated screwdriver. I also recommend leaving a clip lead shorting across the capacitor terminals while working as added insurance. At most, you will blow a fuse if you should forget to remove it when powering up the microwave.

- Connect/disconnect any test leads with the equipment unpowered and unplugged. Use clip leads or solder temporary wires to reach cramped locations or difficult to access locations.
- If you must probe live, put electrical tape over all but the last 1/16" of the test probes to avoid the possibility of an accidental short which could cause damage to various components. Clip the reference end of the meter or scope to the appropriate ground return so that you need to only probe with one hand.
- Perform as many tests as possible with power off and the equipment unplugged. For example, the semiconductors in the power supply section of a TV or monitor can be tested for short circuits with an ohmmeter.
- Use an isolation transformer if there is any chance of contacting line connected circuits. A Variac(tm) is not an isolation transformer! (See the next section with regards to isolation transformers and microwave ovens.) The use of a GFCI (Ground Fault Circuit Interrupter) protected outlet is a good idea but will not protect you from shock from many points in a line connected TV or monitor, or the high voltage side of a microwave oven, for example. A circuit breaker is too slow and insensitive to provide any protection for you or in many cases, your equipment. A GFCI may, however, prevent your scope probe ground from smoking should you accidentally connect an earth grounded scope to a live chassis.
- Don't attempt repair work when you are tired. Not only will you be more careless, but your primary diagnostic tool - deductive reasoning - will not be operating at full capacity.
- Finally, never assume anything without checking it out for yourself! Don't take shortcuts!

As noted, a GFCI (Ground Fault Circuit Interrupter) will NOT protect you from the high voltage since the secondary of the HV transformer is providing this current and any current drawn off of the secondary to ground will not be detected by the GFCI. However, use of a GFCI is desirable to minimize the risk of a shock from the line portions of the circuitry if you don't have an isolation transformer.

An isolation transformer is even limited value as well since the chassis IS the HV return and is a large very tempting place to touch, lean on, or brush up against.

And, of course, none of these devices will protect fools from themselves!

Take extreme care whenever working with the cover off of a microwave oven.

Isolation transformers and microwave ovens

There's little point to using an isolation transformer with a microwave for testing the high voltage circuitry. It would have to be HUGE due to the high power nature of a microwave oven and since the high voltage return is the chassis which is grounded, it won't be terribly useful as noted above. However, an isolation transformer can and should be used to test the primary side circuitry if necessary including interlocks, motors, triac/relay, etc. Disconnect the HV transformer to eliminate the possibility of high voltage shock and to reduce the load.

Actually, the best policy is to NEVER EVER attempt to measure anything in the HV section while the oven is powered - it's almost never needed in any case. Failures are usually easily found by performing test with the oven unplugged. If you insist on making live measurements, connect the meter before power is applied and disconnect or move its probes only after power is removed AND the HV cap has been discharged (even if the meter catches fire or explodes!). Qualified service people have been electrocuted using proper test equipment on microwave ovens!

Troubleshooting tips

Many problems have simple solutions. Don't immediately assume that your problem is some combination of esoteric complex convoluted failures. For a microwave oven, there may be a defective door interlock switch or just a tired fuse.

If you get stuck, sleep on it. Sometimes, just letting the problem bounce around in your head will lead to a different more successful approach or solution. Don't work when you are really tired - it is both dangerous (particularly with microwave ovens) and mostly non-productive (or possibly destructive - very destructive).

If you need to remove the cover or other disassembly, make notes of which screw went where - they may not all be identical. More notes is better than less.

Pill bottles, film canisters, and plastic ice cube trays come in handy for sorting and storing screws and other small parts after disassembly.

Select a work area which is well lighted and where dropped parts can be located - not on a deep pile shag rug. Something like a large plastic tray with a slight lip may come in handy as it prevents small parts from rolling off of the work table. The best location will also be relatively dust free and allow you to suspend your troubleshooting to eat or sleep or think without having to pile everything into a cardboard box for storage.

A basic set of high quality hand tools will be all you need to work on a microwave oven. These do not need to be really expensive but poor quality tools are worse than useless and can cause damage. Stanley or Craftsman are fine. Needed tools include a selection of Philips and straight blade screwdrivers, needlenose pliers, wire cutters and wire strippers.

A medium power soldering iron and rosin core solder (never never use acid core solder or the stuff for sweating copper pipes on electronic equipment) will be needed if you should need to disconnect any soldered wires (on purpose or by accident) or replace soldered components.

However, most of the power components in microwave ovens use solderless connectors (lugs) and replacements usually come with these as well.

See the document: Troubleshooting and Repair of Consumer Electronics Equipment for additional info on soldering and rework techniques and other general information.

An assortment of solderless connectors (lugs and wirenuts) is handy when repairing the internal wiring. A crimping tool will be needed as well but the $4 variety is fine for occasional use.

Old dead microwaves can often be valuable source of hardware and sometimes even components like interlock switches and magnetrons as these components are often interchangeable. While not advocating being a pack rat, this does have its advantages at times.

Test equipment

Don't start with the electronic test equipment, start with some analytical thinking. Many problems associated with consumer electronic equipment do not require a schematic (though one may be useful). The majority of microwave oven problems are easily solved with at most a multimeter (DMM or VOM). You do not need an oscilloscope for microwave oven repair unless you end up trying to fix the logic in the controller - extremely unlikely.

A DMM or VOM is necessary for checking of power supply voltages (NOT the high voltage, however) and testing of interlock switches, fuses, wiring, and most of the components of the microwave generator. This does not need to be expensive but since you will be depending on its readings, reliability is important. Even a relatively inexpensive DMM from Radio Shack will be fine for most repair work. You will wonder how you ever lived without one! Cost: $25-50.

Other useful pieces of 'test equipment':

- A microwave leakage detector. Inexpensive types are readily available at home centers or by mail order. These are not super accurate or sensitive but are better than nothing. Also see the sections: "Microwave leakage meters" and "Simple microwave leak detectors".

- A microwave power detector. These can be purchased or you can make one from a small neon (NE2) or incandescent bulb with its lead wires twisted together. Sometimes these homemade solutions do not survive for long but will definitely confirm that microwave power is present inside the oven chamber. Note: always have a load inside the oven when testing - a cup of water is adequate.

- A thermometer (glass not metal) to monitor water temperature during power tests.

- High voltage probe (professional, not homemade!). However, this is only rarely actually required. Low voltage, resistance, or continuity checks will identify most problems. WARNING: the high voltage in a microwave oven is NEGATIVE (-) with respect to the chassis. Should you accidentally use the wrong test probe polarity with your meter, don't just interchange the probes = it may be last thing you ever do. Unplug the oven, discharge the HV capacitor, and only then change the connections.

There are special magnetron and microwave test instruments but unless you are in the business, these are unnecessary extravagances.

Safe discharging of the high voltage capacitor

It is essential - for your safety and to prevent damage to the device under test as well as your test equipment - that the large high voltage capacitor in the microwave generator be fully discharged before touching anything or making measurements. While these are supposed to include internal bleeder resistors, these can fail. In any case, several minutes may be required for the voltage to drop to negligible levels.

The technique I recommend is to use a high wattage resistor of about 5 to 50 ohms/V of the working voltage of the capacitor. This will prevent the arc-welding associated with screwdriver discharge but will have a short enough time constant so that the capacitor will drop to a low voltage in at most a few seconds (dependent of course on the RC time constant and its original voltage).

- For the high voltage capacitor in a microwave oven, use a 100K ohm resistor rated at least 5 kilovolts and several watts for your discharge widget, with a clip lead to the chassis. As a practical matter, a single resistor like this will be hard to find. So, make one up from a series string of 10 to 20 1/2 W or 1 W normal resistors.

  The reason for specifying the resistor in this way is for voltage hold-off. Common resistors only are rated for 200 to 500 V, but there may be as much as 5 kV on the HV cap. You don't want the HV zapping across the terminals of the resistor. Special high voltage resistors are available but they are expensive and not readily available from common electronics distributors.

- Clip the ground wire to an unpainted spot on the chassis. Use the discharge probe on each side of the capacitor in turn for a second or two. Since the time constant RC is about .1 second, this should drain the charge quickly and safely.

- Then, confirm with a WELL INSULATED screwdriver across the capacitor terminals. If there is a big spark, you will know that somehow, your original attempt was less than entirely successful. There is a very slight chance the capacitor could be damaged by the uncontrolled discharge but at least there will be no danger.

- Finally, it is a good idea to put a clip lead across the capacitor terminals just to be sure it stays fully discharged while you are working in the area. Yes, capacitors have been known to spontaneously regain some charge. At worst, you will blow the fuse upon powering up if you forget to remove it.

WARNING: DO NOT use a DMM for checking voltage on the capacitor unless you have a proper high voltage probe. If your discharging did not work, you may blow everything - including yourself.

A suitable discharge tool can be made as follows:

- Solder one end of the appropriate size resistor (100K ohms, 25W in this case, or a series string of smaller resistors) to a well insulated clip lead about 2 to 3 feet long. Don't just wrap it around - this connection must be secure for safety reasons.

- Solder the other end of the resistor to a well insulated contact point such as a 2 inch length of bare #14 copper wire mounted on the end of a 2 foot piece of PVC or Plexiglas rod which will act as an extension handle.

- Secure the resistor to the insulating rod with some plastic electrical tape.

This discharge tool will keep you safely clear of the danger area. The capacitor discharge indicator circuit described in the document: Capacitor Testing, Safe Discharging and Other Related Information can be built into the discharge tool if desired.

Again, always double check with a reliable high voltage meter or by shorting with an insulated screwdriver!

Reasons to use a resistor and not a screwdriver to discharge capacitors:

1. It will not destroy screwdrivers and capacitor terminals.
2. It will not damage the capacitor (due to the current pulse).
3. It will reduce your spouse's stress level in not having to hear those scary snaps and crackles.

Getting inside a microwave oven

You will void the warranty - at least in principle. There are usually no warranty seals on a microwave so unless you cause visible damage or mangle the screws or plastic, it is unlikely that this would be detected. You need to decide. A microwave still under warranty should probably be returned for warranty service for any covered problems except those with the most obvious and easy solutions.

Unplug the unit! Usually, the sheet metal cover over the top and sides is easily removed after unscrewing 8-16 philips head or hex head sheet metal screws. Most of these are on the back but a few may screw into the sides. They are not usually all the same! At least one of these includes a lockwasher to securely ground the cover to the case.

Note that on some ovens (I've heard that some Sharp models do this), there may also be one screw that is slightly longer than the others to engage a safety case interlock switch and prevent the oven from getting power if it is not present or one of the shorter screws is used in its place. So, with the cover removed, nothing is powered inside (which is a good thing for safety!). But when the cover is replaced with the screws in random locations, there's a high probability that the oven no longer works at all. Kind of like Russian Roulette. And, if it's then taken to a service center, they will know someone has been inside. If less than entirely honest, they can make any sort of claim they want as to what might have been damaged even if all you did was remove and replace the cover without touching anything inside. "The repair will be $195 because you blew out the touch panel by removing the cover."

Therefore, it is essential to make note of any differences in screw types so they can be put back in the same place. The cover will then lift up and off. Note how fingers on the cover interlock with the main cabinet - these are critical to ensure prevention of microwave leakage after reassembly.

Please see Typical Microwave Oven Electronics Bay for parts identification. Not all ovens are this wide open. If yours is a compact unit, everything may be really squeezed together. :) Details will vary depending on manufacturer and model but most of the major components will look fairly similar to those depicted in the photo. Note that for this model, the oven lamp is actually inside the electronics bay right next to the high voltage on the magnetron filament - light bulb changing here is really best left to a professional if you would otherwise not go inside!

Discharge the high voltage capacitor as described in the section: Safe discharging of the high voltage capacitor before even thinking about touching anything.

A schematic showing all of the power generation components is usually glued to the inside of the cover. How much of the controller is included varies but is usually minimal.

Fortunately, all the parts in a microwave can be easily replaced and most of the parts for the microwave generator are readily available from places like MCM Electronics, Dalbani, and Premium Parts.

Reassemble in reverse order. Take particular care to avoid pinching any wires when reinstalling the cover. Fortunately, the inside of a microwave is wide open and this is not difficult. Make sure ALL of the metal fingers around the front edge engage properly with the front panel lip. This is critical to avoid microwave emissions should the waveguide or magnetron become physically damaged in any way. Confirm that the screws you removed go back in the proper locations, particularly the one that grounds the cover to the chassis.

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Principles of Operation

Instant (2 minutes on HIGH) microwave oven theory

Please see Typical Microwave Oven Electronics Bay for parts identification.

A typical microwave oven uses between 500 and 1000 W of microwave energy at 2.45 GHz to heat the food. This heating is caused mainly by the vibration of the water molecules. Thus plastic, glass, or even paper containers will heat only through conduction from the hot food. There is little transfer of energy directly to these materials. This also means that the food does not need to be a conductor of electricity (try heating a cup of distilled water) and that electromagnetic induction (used elsewhere for high frequency non-contact heating) is not involved.

What is significant about 2.45 GHz? Not that much. Water molecules are not resonant at this frequency. A wide range of frequencies will work to heat water efficiently. 2.45 GHz was probably chosen for a number of other reasons including not interfering with existing EM spectrum assignments and convenience in implementation. In addition, the wavelength (about 5 inches) results in reasonable penetration of the microwave energy into the food. The 3 dB (half power) point is about 1 inch for liquid water - half the power is absorbed in the outer 1 inch of depth, another 1/4 of the power in the next inch, and so forth.

From: Barry L. Ornitz (ornitz@tricon.net).)

> "Industrial ovens still often operate at 915 MHz and other frequencies near 6 GHz are also used.
>
> Water has numerous resonances over the entire spectra range, but the lowest frequency resonance is the rotational resonance is around 24 GHz. Other

resonances occur in the millimeter wave range through the infrared.

For references, check books on microwave spectroscopy by Townes and Gordy."

Since the oven chamber cavity is a good reflector of microwaves, nearly all the energy generated by the oven is available to heat the food and heating speed is thus only dependent on the available power and how much food is being cooked. Ignoring losses through convection, the time to heat food is roughly proportional to its weight. Thus two cups of water will take around twice as long to bring to a boil as one.

Heating is not (as popularly assumed) from the inside out. The penetration depth of the microwave energy is a few cm so that the outside is cooked faster than the inside. However, unlike a conventional oven, the microwave energy does penetrate these few cm rather than being totally applied to the exterior of the food. The misconception may arise when sampling something like a pie filling just out of the microwave (or conventional oven for that matter). Since the pie can only cool from the outside, the interior filling will appear to be much hotter than the crust and will remain that way for a long time.

One very real effect that may occur with liquids is superheating. It is possible to heat a pure liquid like water to above its boiling point if there are no centers for bubbles to form such as dust specks or container imperfections. Such a superheated liquid may boil suddenly and violently upon removal from the oven with dangerous consequences. This can take place in a microwave since the heating is relatively uniform throughout the liquid. With a stovetop, heating is via conduction from the burner or coil and there will be ample opportunity for small bubbles to form on the bottom long before the entire volume has reached the boiling point.

Most metal objects should be excluded from a microwave oven as any sharp edges (areas of high electric field gradient) may create sparking or arcing which at the very least is a fire hazard. Microwave safe metal shelves will have nicely rounded corners.

A microwave oven should never be operated without anything inside as the microwave generator then has no load - all the energy bounces around inside an a great deal is reflected back to the source. This may cause expensive damage to the magnetron and other components.

Why don't microwaves leak out from through the glass?

"I am trying to find out what the glass on a microwave consists of exactly. i have not been able to get a better answer than 'a wire mesh'. if you can help, i would greatly appreciate it."

There *is* a wire mesh embedded in the glass panel. Since the holes in the mesh are much much smaller than the wavelength of the 2.45 GHz microwaves (about 5 inches or 12.5 cm), it is essentially opaque to microwaves and essentially all the energy is reflected back into the oven cavity.

(From: Filip (I'll buy a vowel) Gieszczykiewicz (filipg@repairfaq.org).)

Greetings. Did you ever see a "mesh" satellite disk up close? You will note that it looks much like it's made out of simple wire mesh that you can get in a hardware store (in the USA, it's called "chicken fence" :-). The reason this works is that the wave that the dish picks up is longer than the hole in the mesh. Consider bouncing a tennis ball on the "wire mesh" in the microwave - it WOULD work because the ball is bigger than the holes. The wave in the microwave is about 2.5cm "long" ... as long as the holes are smaller than that (actually, you want them as small as possible - without affecting the "watching the food" - to minimize any stray and harmonic waves from escaping... like bouncing tennis and golf and ping-pong balls and marbles off the mesh - you want to catch all the possible sizes - yet still be able to see through it) they will not let anything out of the oven.

BTW, it's not really "glass" but rather a 'sandwich' of glass, from the outside, wire mesh (usually a sheet of metal which is either stamped or drilled with a hole pattern - like a color TV CRT mask!), and followed by a sheet of glass or plastic to make sure that food splatters and vapor condensation are easy to clean - imagine scraping the mesh!

How a microwave oven works

The operation of a microwave oven is really very simple. It consists of two parts: the controller and the microwave generator.

A schematic diagram of the microwave generating circuitry and portions of the controller is usually glued to the inside of the cover.

The controller is what times the cooking by turning the microwave energy on and off. Power level is determined by the ratio of on time to off time in a 10-30 second cycle.

The microwave generator takes AC line power. steps it up to a high voltage, and applies this to a special type of vacuum tube called a magnetron - little changed from its invention during World War II (for Radar).

Controller

The controller usually includes a microcomputer, though very inexpensive units may simply have a mechanical timer (which ironically, is probably more expensive to manufacture!). The controller runs the digital clock and cook timer; sets microwave power levels; runs the display; and in high performance ovens, monitors the moisture or temperature sensors.

Power level in most microwave ovens is set by pulse width control of the microwave generator usually with a cycle that lasts 10-30 seconds. For example, HIGH will be continuous on, MEDIUM may be 10 seconds on, 10 seconds off, and LOW may be 5 seconds on, 15 seconds off. The power ratios are not quite linear as there is a 1 to 3 second warmup period after microwave power is switched on.

However, some models use finer control, even to the point of a continuous range of power. These are typically "inverter" models which use a more sophisticated type of power supply than the simple high voltage transformer, capacitor, rectifier, system described below. However, there have been some back in the 1970s that did this with a 1 second or so pulse width modulated cycle, fast enough to have the same effect as continuous control for all practical purposes.

The operating voltages for the controller usually are derived from a stepdown transformer. The controller activates the microwave generating circuitry using either a relay or triac.

Sensors

More sophisticated ovens may include various sensors. Most common are probes for temperature and moisture. A convection oven will include a temperature sensor above the oven chamber.

Since these sensors are exposed to the food or its vapors, failures of the sensor probes themselves are common.

Cooling fans

Since 30 to 50 percent of the power into a microwave oven is dissipated as heat in the Magnetron, cooling is extremely important. Always inspect the cooling fan/motor for dust and dirt and lubricate if necessary. A couple of drops of electric motor oil or 3-in-One will go a long way. If there are any belts, inspect for deterioration and replace if necessary.

An oven that shuts off after a few minutes of operation could have a cooling problem, a defective overtemperature thermostat, a bad magnetron, or is being operated from very high AC line voltage increasing power to the oven.

One interesting note: Since 30 to 50 percent of the power goes out the vents in the back as heat, a microwave oven is really only more efficient than conventional means such as a stovetop or gas or electric oven for heating small quantities of anything. With a normal oven or stovetop, wasted energy goes into heating the pot or oven, the air, and so on. However, this is relatively independent of the quantity of food and may be considered to be a fixed overhead. Therefore, there is a crossover point beyond which it is more efficient to use conventional heat than high tech microwaves.

Microwave generator

This is the subsystem that converts AC line power into microwave energy. The majority of microwave ovens use a brute force approach which consists of 5 parts: high voltage (HV) transformer running off the AC line, HV rectifier diode, HV capacitor, magnetron, waveguide to oven chamber. (A few employ solid state inverter in place of the simple HV transformer. These will be discussed later.)

The most common microwave generator consists of the following:

- High Voltage Transformer. Typically has a secondary of around 2,000 VRMS at 0.5 to 1 amp - more or less depending on the power rating of the oven. There will also be a low voltage winding for the Magnetron filament (3.3 V at 10 A is typical).

  You cannot miss this as it is the largest and heaviest component visible once the cover is removed. There will be a pair of quick-connect terminals for the AC input, a pair of leads for the Magnetron filament. and a single connection for the HV output. The HV return will be fastened directly to the transformer frame and thus the chassis.

  These transformers are designed with as little copper as possible. The primary for 115 VAC is typically only 120 turns of thick wire - thus about 1 turn per volt input and output (this is about 1/4th as many turns as in a "normal" power transformer. (It's usually possible to count the primary turns by examining how it is wound - no disassembly required!) So there would be about 3 turns for the magnetron filament and 2080 turns for the high voltage winding for the transformer mentioned above. The reason they can get away with so few turns is that it operates fully loaded about 90 percent of the time but is still on the hairy edge of core saturation. The HV components are actually matched to the HV transformer characteristics. Performance will suffer if the uF value of a replacement HV capacitor is not close to that of the original.

  There is also generally a "magnetic shunt" in the core of the transformer. This provides some current limiting, possibly to compensate for various magnetron load conditions. However, it's not enough to provide any reduction in the likelihood of electrocution should you come in contact with the HV winding!

- Rectifier - usually rated 12,000 to 15,000 PRV at around 0.5 amp. Most commonly, this will be rectangular or cylindrical, about 0.5 inch long with wire leads. Sometimes, it is a box bolted to the chassis. One end will be electrically connected to the chassis.

- Capacitor - 0.65 to 1.2 uF at a working voltage of around 2,000 VAC. Note that this use of 'working voltage' may be deceiving as the actual voltage on the capacitor may exceed this value during operation. The capacitor is metal cased with quick-connect terminals on top (one end). Always discharge the capacitor as described below before touching anything inside once the cover is removed.

- Magnetron - the microwave producing tube includes a heated filament cathode, multiple resonant cavities with a pair of permanent ceramic ring magnets to force the electron beams into helical orbits, and output antenna. The magnetron is most often box shaped with cooling fins in its midsection, the filament/HV connections on the bottom section, and the antenna (hidden by the waveguide) on top. Sometimes, it is cylindrical in shape but this is less common. The frequency of the microwaves is usually 2.45 GHz.

When salvaging parts from dead microwave ovens, save the HV components (transformer, capacitor, and diode) as a group (assuming all are still good). Then, if a repair is needed to another oven it may be better to replace all 3 both because this eliminates uncertainty if more than 1 part failed or is marginal, and they will have been designed to have the best compatibility.

High voltage transformer

(From: John De Armond.)

The transformer goes by several names, depending on where you are. Variable reluctance, leakage flux, stray flux, etc. It is exactly the same construction and operating principle as a neon transformer, some kinds of HID light ballasts and some series streetlight constant current transformers.

The core is an almost standard "E" core (or "H" core if you prefer) with one exception. The center leg has an air gap. The windings are on the end legs of the "E" instead of the center leg.

There are two magnetic paths around the core for the field set up by the primary to travel. Around the periphery and across the secondary and around the center leg and across the air gap. The field that travels along the center leg does not cross the secondary and induces no voltage.

With no load applied, the bulk of the field travels the peripheral, very much lower reluctance solid iron path, inducing full secondary voltage proportional to the turns ratio. As current flows in the secondary, counter-MMF raises the reluctance of the peripheral path so that some of the flux travels through the center leg. With less flux traveling around the periphery and cutting across the secondary, the secondary voltage drops as the current remains about the same. At the limit, if the secondary is shorted, the peripheral path has so much reluctance that most of the flux travels the center leg and across the air gap. The same current as before flows through the secondary but at zero volts.

When the dimensions of the core and gap are set up correctly, the transformer behaves as an almost perfect constant current device. That is, the secondary voltage varies as necessary to keep the same current flowing through a varying load. Just what the doctor ordered to keep the magnetron happy.

The secondary current can be increased by opening up the air gap. This raises the reluctance of that path and forces more field through the secondary leg. Closing the gap has the opposite effect.

The center leg is often called the magnetic shunt and frequently it is a separate piece of laminated iron stuck between the coils and TIG welded in place. It is a common trick for Tesla Coilers to open up a neon transformer and either knock out the shunt entirely or grind it down to open the air gap. This modification causes the transformer to output much more current than it is designed for - for a little while, at least :-) The same thing works with microwave oven transformers (MOT).

This design in a microwave oven is a vital part of keeping the magnetron anode current within spec. The magnetron is electrically a diode. A diode that isn't emission-limited would draw destructive current if not externally limited. With this design, the filament can be heated good and hot for long life and not have the tube run away. The design also is vital for protecting the magnetron from potentially damaging conditions such as operating the oven empty, arcing, etc.

It's popular to use several MOTs to build an arc welder. This works quite well specifically because these transformers are constant-current devices - exactly the characteristic stick welding needs. If they were conventional transformers, the first time the rod touched the work and shorted the secondary, fault current would flow and the breaker would trip or blue smoke would leak out.

Along similar lines, one can cut off the high voltage secondary and replace it with a suitable number of turns of heavy wire, connect a bridge rectifier and have a nice constant current battery charger. Select the turns carefully and it'll do the bulk/absorption stages of the smart 3 stage charging algorithm.

Magnetron construction and operation

The cavity magnetron was invented by the British before World War II. It is considered by many to be the invention most critical to the Allied victory in Europe.

The story goes that shortly after the War, a researcher at the Raytheon Corporation, Dr. Percy Spencer, was standing near one of the high power radar units and noticed that a candy bar in his shirt pocket had softened. In the typical 'I have to know why this happened' mentality of a true scientist, he decided to investigate further. The Amana Radarange and the entire future microwave oven industry were the result.

Here are two descriptions of magnetron construction. The first is what you will likely find if you go to a library and read about radar. (Some really old microwave ovens may use the classic design as well.) This is followed by my autopsy of a dead magnetron of the type that is probably in the microwave oven in your kitchen. (Items (1) to (6) in the following sections apply to each type while items (7) to (9) apply to both types.)

For more detailed information with some nice diagrams, see the articles at the Microtech Web Site. Topics include basic microwave theory as well as a complete discussion of microwave oven magnetron construction and principles of operation.

Magnetron construction - basic textbook description

This is the description you will find in any textbook on radar or microwave engineering. The original Amana Radarange and other early microwave ovens likely used this design as well.

1. A centrally located cylindrical electron emitting cathode. This is supplied with pulsed or continuous power of many thousands of volts (negative with respect to the anode.

2. A cylindrical anode block surrounding but separate and well insulated from the cathode.

3. Multiple cylindrical resonator cavities at a fixed radius from the cathode bored in the anode block. Channels link the cavities to the central area in which the cathode is located.

   The wavelength of the microwave energy is approximately 7.94 times the diameter of the cavities. (For the frequency of 2.45 GHz (12.4 cm) used in a microwave oven this would result in a cavity diameter of approximately .62" (15.7 mm).

4. An antenna pickup in one of the cylindrical cavities which couples the microwave energy to the waveguide.

5. The entire assembly is placed in a powerful magnetic field (several thousand Gauss compared to the Earth's magnetic field of about .5 Gauss). This is usually supplied by a permanent magnet though electromagnets have been also used. The original designs used huge somewhat horseshoe shaped permanent magnets which were among the most powerful of the day.

6. Cooling of the anode block must be provided by forced air, water, or oil since the microwave generation process is only about 60 to 75 percent efficient and these are often high power tubes (many kilowatts).

Magnetron construction - modern microwave oven

This description is specifically for the 2M214 (which I disassembled) or similar types used in the majority of medium-to-high power units. However, nearly all other magnetrons used in modern domestic microwave ovens should be very similar.

The item numbers are referenced to the diagram in the section: Cross section diagram of typical magnetron.

Also see this photo of the Typical Magnetron Anode and Resonant Structure. This is a view looking up through the anode cylinder from the filament end of the tube. See the text below for parts names and dimensions.

1. The filament and cathode are one in the same and made of solid tungsten wire, about .020" (.5 mm) diameter, formed in a helix with about 8 to 12 turns, 5/32" (4

mm) diameter and just over 3/8" (9.5 mm) in length. The cathode is coated with a material which is good for electron emission.

Note: this coating is the only material contained in the microwave oven magnetron that might be at all hazardous. Beryllium, a toxic metal, may be used in the form of a ceramic of beryllium oxide (BeO) in large radar magnetrons due to its excellent heat conductivity. But should not be present in modern domestic microwave ovens. However, see the section: SAFETY.

The filament gets its power via a pair of high current RF chokes - a dozen or so turns of heavy wire on a ferrite core - to prevent microwave leakage back into the filament circuit and electronics bay of the oven. Typical filament power is 3.3 VAC at 10 A.

The cathode is supplied with a pulsating negative voltage with a peak value of up to 5,000 V.

2. The anode is a cylinder made from .062" (1.5 mm) thick copper with an inside diameter of 1-3/8" (35 mm) and a length of about 1" (25.4 mm).

   Steel plates (which probably help to shape the magnetic field, see below) and thin steel covers (to which the filament and antenna insulators are sealed) are welded to the ends of the cylinder.

   The filament leads/supports enter through a cylindrical ceramic insulator sealed to the bottom cover and then pass through a hole in the bottom end plate.

3. Rather than cylindrical cavities (as you would find in most descriptions of radar magnetrons), there are a set of 10 copper vanes .062" (1.5 mm) thick and approximately 1/2" (12.7 mm) long by 3/8" (9.5 mm) wide. These are brazed or silver soldered to the inside wall of the cylinder facing inward leaving a 5/16" (8 mm) central area clear for the filament/cathode.

   Surrounding this space are the .062" (1.5 mm) thick edges of the 10 vanes with gaps of approximately .04" (1 mm) between them.

   Copper shorting rings at both ends near the center join alternating vanes. Thus, all the even numbered vanes are shorted to each other and all the odd numbered vanes are shorted to each other. Of course, all the rings are also all shorted at the outside where they are joined to the inner wall of the cylinder.

   This structure results in multiple resonant cavities which behave like sets of very high quality low loss L-C tuned circuits with a sharp peak at 2.45 GHz. At this high frequency, individual inductors and capacitors are not used. The inductance and capacitance are provided by the precise configuration and spacing of the copper vanes, shorting rings, and anode cylinder.

4. A connection is made near the middle of a single vane to act as the output power takeoff. It passes through a hole in the top end plate, exits the tube via a cylindrical ceramic insulator sealed to the top cover, and attaches to the pressed-on bu?ll-nose antenna cap.

5. The entire assembly is placed in a powerful magnetic field (several thousand Gauss compared to the Earth's magnetic field of about .5 Gauss). This is provided by a pair of ceramic ring magnets placed against the top and bottom covers of the anode cylinder. For the 2M214, these are about 2-1/8" (54 mm) OD, 1-13/16" (46 mm) ID, 1/2" (12.7 mm) thick.

6. A set of thin aluminum fins act as a heat sink for removing the significant amount of wasted heat produced by the microwave generation process since it is only about 60 to 75 percent efficient. These are press fit on the magnetron anode and also in contact with the magnetron case. There will always be a cooling fan to blow air through this assembly.

   The anode and magnetron case are at ground potential and connected to the chassis.

Magnetron construction - common features

The following items apply to all types of magnetrons.

7. The gap between the cathode and anode, and the resonant cavities, are all in a vacuum.

8. When powered, electrons stream from the cathode to the anode. The magnetic field forces them to travel in curved paths in bunches like the spokes of a wheel. The simplest way to describe what happens is that the electron bunches brush against the openings of the resonating cavities in the anode and excite microwave production in a way analogous to what happens when you blow across the top of a Coke bottle or through a whistle.

9. The frequency/wavelength of the microwaves is mostly determined by the size and shape of the resonating cavities - not by the magnetic field as is popularly thought. However, the strength of the magnetic field does affect the threshold voltage (the minimum anode voltage required for the magnetron to generate any microwaves), power output, and efficiency.

Cross section diagram of typical magnetron

The really extraordinary ASCII art below represents (or is supposed to represent) a cross section of the 2M214 type magnetron (not to scale) through the center as viewed from the side.

```
                       ________
                      |  ____  |
                      |_|    |_|  Antenna cap
                      / |____| \
                     |  | || |  | Antenna insulator
                     |  | || |  |
             xxxxxxxx|__| || |__|xxxxxxxx RF sealing gasket
 ____________________|    ||    |____________________
|        |       (5)||    ||    ||       (5)|        |
|        |   Top    ||    ||    ||   Top    |        |
|        |  Magnet  ||    ||    ||  Magnet  |        | Outer case
|        |__________||    ||    ||__________|        |
|              ______|     \\   |______              |
|             /____    (7)   \\    ____\             |
|____________||    \__  ______ \\ /    ||____________|
```

```
|            ||_______ |__  __| _\\ ___||            |
|____________||       | o || o |  ||(4)||____________|
|            ||       | o || o |       ||        (6) | Heat sink fins
|____________|| Vane  | o || o |  Vane ||____________|
|            || (3)   | o || o |  (3)  ||            |
|____________||       | o || o |       ||____________| o: Filament
|            ||_______|(1)|| o |_______||            |    helix
|____________||     __ |_||||_| __     ||____________|
|            ||____/   || ||      \____||<--  (2)    |
|             \______   \\ \\    ______/             |
|         __________ |  ||  ||  | __________         |
|        |       (5)||  ||  ||  ||       (5)|        |
|        |  Bottom  ||  ||  ||  ||  Bottom  |        |
|        |  Magnet  ||  ||  ||  ||  Magnet  |        |
|________|__________||  ||  ||  ||__________|________|
    |                |__||__||__|                |
    |                 | ||  || |  Filament       |
    |                 | ||  || |  insulator      |
    |   (RF chokes    |_||__||_|                 |
    |    not shown)     ||  ||  Filament/cathode |
    |                   ||  ||  connections      |
    |____________________________________________|
```

Microwave generator circuit diagram

Nearly all microwave ovens use basically the same design for the microwave generator. This has resulted in a relatively simple system manufactured at low cost.

The typical circuit is shown below. This is the sort of diagram you are likely to find pasted inside the metal cover. Only the power circuits are likely included (not the controller unless it is a simple motor driven timer) but since most problems will be in the microwave generator, this schematic may be all you need.

```
                                     || +------------------------+
                                     ||( 3.3 VAC, 10 A, typical  |
                       TP  Relay or  || +------------+------+FA F| Magnetron
      _    I       I   __    Triac   ||              |    +-|----|-+
  o--- _---/ --+---/ --  ----/ ----+ || +------||----+    | |_  _| |
               |                    )||( HV Cap      |    |   \/   |
 AC           I \ I=Interlock       )||(          __|__  |   ___  |
Line           |  TP=Thermal Prot.  )||( 2,000 VAC _\_/_  +----|:--+
  o------------+-------------------+ ||( 0.5 A       | HV      |'--> Micro-
                                     ||( typical     | Diode   |      waves
      (Controller not shown)         || +------------+---------+
                                                    _|_
                                                     -  Chassis ground
```

Note the unusual circuit configuration - the magnetron is across the diode, not the capacitor as in a 'normal' power supply. What this means is that the peak voltage across the magnetron is the transformer secondary + the voltage across the capacitor, so the peaks will approach the peak-peak value of the transformer or nearly 5000 V in the example above. This is a half wave voltage doubler. The output waveform looks like a sinusoid with a p-p voltage equal to the p-p voltage of the transformer secondary with its positive peaks at chassis ground (no load). The peaks are negative with respect to the chassis. The negative peaks will get squashed somewhat under load. Take extreme care - up to 5000 V at AMPs available! WARNING: Never attempt to view this waveform on an oscilloscope unless you have a commercial high voltage probe and know how to use it safely!

The easiest way to analyze the half wave doubler operation is with the magnetron (temporarily) removed from the circuit. Then, it becomes a simple half wave rectifier/filter so far as the voltage acrtoss the capacitor is concerned - which will be approximately V(peak) = V(RMS) * 1.414 where V(RMS) is the output of the high voltage transformer. The voltage across the HV rectifier will then be: V(peak) + V where V is the waveform out of the transformer. The magnetron load, being across the HV diode, reduces the peak value of this somewhat - where most of its conduction takes place.

Note that there is a difference in the labels on the filament connections of the magnetron. Functionally, it probably doesn't matter which way they are connected. However, the typical schematic (as above) shows FA going to the node attached to the Anode of the HV diode, while F goes to the lone Filament terminal on the HV transformer.

WARNING: What this implies is that if the magnetron is not present or is not drawing power for some reason - like an open filament - up to V(peak) will still be present across the capacitor when power is removed. At the end of normal operation, some of this will likely be discharged immediately but will not likely go below about 2,000 V due to the load since the magnetron does not conduct at low voltages.

Other types of power supplies have been used in a few models - including high frequency inverters - but it is hard to beat the simplicity, low cost, and reliability of the half wave doubler configuration. See the section: High frequency inverter type HV power supplies.

There is also usually a bleeder resistor as part of the capacitor, not shown. HOWEVER: DO NOT ASSUME THAT THIS IS SUFFICIENT TO DISCHARGE THE CAPACITOR - ALWAYS DO THIS IF YOU NEED TO TOUCH ANYTHING IN THE MICROWAVE GENERATOR AFTER THE OVEN HAS BEEN POWERED. The bleeder may be defective and open as this does not effect operation of oven and/or the time constant may be long - minutes. Some ovens may not have a bleeder at all.

In addition, there will likely be an over-temperature thermostat - thermal protector - somewhere in the primary circuit, often bolted to the magnetron case. There may also be a thermal fuse or other protector physically elsewhere but in series with the primary to the high voltage transformer.

Other parts of the switched primary circuit include the oven interlock switches, cooling fan, turntable motor (if any), oven light, etc.

Interlock switches

Various door interlock switches prevent inadvertent generation of microwaves unless the door is closed completely. At least one of these will be directly in series with the transformer primary so that a short in the relay or triac cannot accidentally turn on the microwaves with the door open. The interlocks must be activated in the correct sequence when the door is closed or opened.

Interestingly, another interlock is set up to directly short the power line if it is activated in an incorrect sequence. The interlocks are designed so that if the door is correctly aligned, they will sequence correctly. Otherwise, a short will be put across the power line causing the fuse to blow forcing the oven to be serviced. This makes it more difficult for an ignorant consumer to just bypass the door interlocks should they fail or to run the oven with an open door as a room heater - and protects the manufacturer from lawsuits. (That interlock may be known as a "dummy switch" for obvious reasons and is often not even mentioned in the schematic/parts manifest.) Of course, should that switch ever actually be used, not only will the fuse blow, but the switch contacts will likely be damaged by the high initial current! This also means it probably wouldn't be a bad idea to replace the interlock switch which might have been affected if your oven fails with a blown fuse due to a door problem.

Failed door interlocks account for the majority of microwave oven problems - perhaps as high as 75 percent. This is not surprising considering that two of the three switches carry the full oven current - any deterioration of the contacts results in increased resistance leading to their heating and further deterioration. And, opening the door to interrupt a cook cycle results in arcing at the contacts. Complete meltdowns are not unusual! If any defective door switches are found, it is probably a good idea to replace all of them as long as the oven is already apart.

The typical door switches and their function:

- **Door Sensing**: Input to the microcontroller to indicate the state of the door.
- **Interlock Monitor**: Shorts out the AC line (and blows the main fuse) should the Primary Interlock not open due to incorrect sequencing of the door switches or a failed switch.
- **Primary Interlock**: In series with the high voltage (magnetron) power supply so cuts power when the door is open.

Note that if the Door Sensing switch should malfunction, peculiar behavior may occur (like the fan or turntable operating at the wrong time) but should never result in microwaves being generated with the door open.

- Back to Microwave Oven Repair FAQ Table of Contents.

Troubleshooting Guide

Instant troubleshooting chart - most common problems and possible causes

The following chart lists a variety of common problems and nearly all possible causes. Diagnostic procedures will then be needed to determine which actually apply. The 'possible causes' are listed in *approximate* order of likelihood. Most of these problems are covered in more detail elsewhere in this document.

While this chart lists many problems, it is does not cover everything that can go wrong. However, it can be a starting point for guiding your thinking in the proper direction. Even if not listed here, your particular problem may still be dealt with elsewhere in this document.

- Problem: Totally dead oven.
  Possible causes:

  1. No power to outlet (blown fuse or tripped breaker or GFCI).
  2. Blown main fuse - likely due to other problems.
  3. Open thermal protector or thermal fuse.
  4. Defective controller or its power supply.
  5. Clock needs to be set before other functions will operate (some models).

- Problem: Totally dead oven after repair.
  Possible causes:

  1. Cabinet screws replaced in incorrect location (safety interlock not engaged).
  2. Any number of screwups. :)

- Problem: No response to any buttons on touchpad.
  Possible causes:

  1. Door is not closed (some models).
  2. You waited too long (open and close door to wake it up).
  3. Controller is confused (pull plug for a minute or two to reset).
  4. Defective interlock switches.
  5. Faulty controller or its power supply.
  6. Touchpad or controller board contaminated by overenthusiastic cleaning.
  7. Defective/damaged touchpad.

- Problem: Oven runs when door is still open.
  Possible causes:

  1. Damaged interlock assembly.
  2. Cooling fans (only) running due to bad sensor or still warm.

- Problem: Oven starts on its own as soon as door is closed.
  Possible causes:

1. Defective triac or relay.
2. Controller is confused (pull plug for a minute or two to reset).
3. Defective controller or its power supply.
4. Touchpad or controller board contaminated by overenthusiastic cleaning.
5. Defective/damaged touchpad.

- Problem: Oven works but display is blank.
  Possible causes:

  1. Defective controller or its power supply.
  2. Broken display panel.
  3. Oven needs to be reset (pull plug for a minute or two to reset).

- Problem: Whacked out controller or incorrect operation.
  Possible causes:

  1. Previous or multipart cook cycle not complete.
  2. Controller is confused (pull plug for a minute or two to reset).
  3. Defective controller or its power supply.
  4. Touchpad or controller board contaminated by overenthusiastic cleaning.
  5. Defective/damaged touchpad.
  6. Defective sensor (particulalry covection/mirowave combos).

- Problem: Erratic behavior.
  Possible causes:

  1. Previous or multipart cook cycle not complete.
  2. Bad connections in controller or microwave generator.
  3. Faulty relay - primary (or HV side, much less commonly used).
  4. Defective controller or its power supply.
  5. Bad contacts/connections on mechanical timers. Intermittent fuse.
  6. Power surge at start of cook cycle confusing controller.
  7. Microwave (RF) leakage into electronics bay.

- Problem: Some keys on the touchpad do not function or perform the wrong action.
  Possible causes:

  1. Touchpad or controller board contaminated by overenthusiastic cleaning.
  2. Defective/damaged touchpad.
  3. Controller is confused (pull plug for a minute or two to reset).
  4. Faulty controller.

- Problem: Microwave oven does not respond to START button.
  Possible causes:

  1. Defective START button.
  2. Faulty interlock switches.
  3. Door is not securely closed.
  4. Faulty controller.
  5. You waited too long - open and close door to wake it up!

- Problem: No heat but otherwise normal operation.
  Possible causes:

  1. Blown fuse in HV transformer primary circuit or HV fuse (if used).
  2. Bad connections (particularly to magnetron filament).
  3. Open thermal protector or thermal fuse.
  4. Open HV capacitor, HV diode, HV transformer, or magnetron filament.
  5. Shorted HV diode, HV capacitor (will blow a fuse), or magnetron.
  6. Damaged protective VDR from filament to chassis (not commonly used).
  7. Defective HV relay (not commonly used).

- Problem: Timer and light work but no heat, cooling fan, or turntable rotation.
  Possible causes:

  1. Defective (lower) door interlock switch or door not closing fully.
  2. Faulty relay or triac.

- Problem: Fuse blows when closing or opening door:
  Possible causes:

  1. Defective door interlock switch(s).
  2. Interlock switch knocked out of position.
  3. Misaligned door.

- Problem: Loud hum and/or burning smell when attempting to cook.
  Possible causes:

  1. Shorted HV diode, magnetron.
  2. Burnt carbonized food in or above oven chamber.
  3. Shorted winding in HV transformer.
  4. Frayed insulation on HV wiring.

- Problem: Arcing in or above oven chamber.
  Possible causes:

  1. Burnt carbonized food deposits.
  2. Exposed sharp metal edges.

- Problem: Fuse blows when initiating cook cycle.
  Possible causes:

  1. Defective interlock switches or misaligned door.
  2. Shorted HV capacitor.
  3. Shorted HV diode.
  4. Shorted magnetron (probably won't blow main fuse but HV fuse if used).
  5. Defective triac.
  6. Old age or power surges.
  7. Defective HV transformer.
  8. Short in wiring due to vibration or poor manufacturing.

- Problem: Fuse blows when microwave shuts off (during or at end of cook cycle).
  Possible causes:

  1. Defective triac (doesn't turn off properly).
  2. Defective relay.
  3. Shorting wires.

- Problem: Oven heats on high setting regardless of power setting.
  Possible causes:

  1. Faulty primary relay or triac or HV relay (not commonly used).
  2. Faulty controller.

- Problem: Oven immediately starts to cook when door is closed.
  Possible causes:

  1. Shorted relay or triac.
  2. Faulty controller.

- Problem: Oven heats but power seems low or erratic.
  Possible causes:

  1. Low line voltage.
  2. Magnetron with low emission.
  3. Faulty controller or set for wrong mode.
  4. Stirrer (or turntable) not working.
  5. Intermittent connections to magnetron filament or elsewhere.
  6. Faulty primary relay or triac or HV relay (not commonly used).
  7. Damaged protective VDR from filament to chassis (not commonly used).

- Problem: Oven heats but shuts off randomly.
  Possible causes:

  1. Overheating due to blocked air vents or inoperative cooling fan.
  2. Overheating due to bad magnetron.
  3. Bad connections in controller or microwave generator.
  4. Faulty interlock switch or marginal door alignment.
  5. Faulty controller.
  6. Overheating due to extremely high line voltage.
  7. Stuck stirrer fan resulting hot spots detected by sensors.

- Problem: Oven makes (possibly erratic) buzzing noise when heating.
  Possible causes:

  1. Fan blades hitting support or shroud.
  2. Vibrating sheet metal.
  3. Vibrating transformer laminations.
  4. Turntable or stirrer hitting some debris.

- Problem: Oven light does not work.

Possible causes:

1. Burnt out bulb :-).
2. Bad connections.

- Problem: Fans or turntables that do not work.
  Possible causes:

  1. Gummed up lubrication or bad motor bearing(s).
  2. Loose or broken belt.
  3. Bad motor.
  4. Bad thermostat.
  5. Bad connections.

What can go wrong

The most common problems occur in the microwave generating portion of the system, though the controller can be blown by a lightning strike or other power surge. Bad interlock switches probably account for the majority of microwave oven problems. Also, since the touchpad is exposed, there is a chance that it can get wet or damaged. If wet, a week or so of non-use may cure keys that don't work. If damaged, it will probably need to be replaced - this is straightforward if the part can be obtained, usually direct from the manufacturer. Unfortunately, it is an expensive part ($20-50 typical).

The interlock switches, being electromechanical can fail to complete the primary circuit on an oven which appears to operate normally with no blown fuses but no heat as well. Faulty interlocks or a misaligned door may result in the fuse blowing as described above due to the incorrect sequencing of the door interlock switches. Failed interlocks are considered to be the most common problems with microwave ovens, perhaps as high as 75% of all failures. See the section: Testing and replacing of interlock switches.

No adjustments should ever be required for a microwave oven and there are no screws to turn so don't look for any!

General system problems

The following problems are likely power or controller related and not in the microwave generator unless due to a blown fuse or bad/intermittent connections:

- Totally dead oven.
- No response to any buttons on touchpad
- Oven runs when door is still open.
- Oven starts on its own as soon as door is closed.
- Oven works but display is blank.
- Whacked out controller or incorrect operation.
- Erratic behavior.
- Some keys on the touchpad do not function or perform the wrong action.
- Microwave oven does not respond to START button.

First, unplug the microwave oven for a couple of minutes. Sometimes, the microcontroller will get into a whacko mode for some unknown reason - perhaps a power surge - and simply needs to be reset. The problem may never reoccur.

Note: when working on controller related problems, unplug the connection to the microwave generator (HV transformer primary) from the power relay or triac - it is often a separate connector. This will prevent any possible accidental generation of microwave energy as well as eliminating the high voltage (but not the AC line) shock hazard during servicing.

If this does not help, there is likely a problem with the controller circuitry or its power and you will have to get inside the oven.

Uninvited guests

Some cockroaches (or other lower life forms) may have taken up residence on the controller circuit board. It is warm, cozy, safe, and from their point of view makes an ideal habitat. If you got the microwave oven from a flea market, garage sale, the curb, a relative, or friend, or if your kitchen isn't the cleanest in the world, such visitors are quite possible. Creatures with six or more legs (well, some two legged varieties as well) are not known for their skills in the areas of housekeeping and personal hygiene.

Clean the circuit board and connectors thoroughly with water and then isopropyl alcohol. Dry completely. Inspect the circuit traces for corrosion or other damage. If there are any actual breaks, these will have be be jumpered with fine wire and then soldered. Hopefully, no electronic components were affected though there is always a slight possibility of other problems.

Totally dead oven

First, check power to the outlet using a lamp or radio you know works. The fuse or circuit breaker at your service panel may have blown/tripped due to an overload or fault in the microwave oven or some other appliance. You may just have too many appliances plugged into this circuit - microwave ovens are high current appliances and should be on a dedicated circuit if possible. If you attempt to run a heating appliance like a toaster or fryer at the same time, you *will* blow the fuse or trip the circuit breaker. A refrigerator should never be plugged into the same circuit for this reason as well - you really don't want it to be without power because of your popcorn!

If you find the fuse blown or circuit breaker tripped, unplug everything from the circuit to which the microwave is connected (keep in mind that other outlets may be fed from the same circuit). Replace the fuse or reset the circuit breaker. If the same thing happens again, you have a problem with the outlet or other wiring on the same branch circuit. If plugging in the microwave causes the fuse to blow or circuit breaker to trip immediately, there is a short circuit in the power cord or elsewhere.

The microwave oven may be powered from a GFCI outlet or downstream of one and the GFCI may have tripped. (Removing a broken oven lamp has been known to happen.) The GFCI outlet may not be in an obvious location but first check the countertop outlets. The tripped GFCI could be in the garage or almost anywhere else! Pushing the RESET button may be all that's needed.

Next, try to set the clock. With some ovens the screen will be totally blank following a power outage - there may be nothing wrong with it. Furthermore, some ovens will not allow you perform any cooking related actions until the clock is set to a valid time.

Assuming these are not your problems, a fuse has probably blown although a dead controller is a possibility.

If the main fuse is upstream of the controller, then any short circuit in the microwave generator will also disable the controller and display. If this is the case, then putting in a new fuse will enable the touchpad/display to function but may blow again as soon as a cook cycle is initiated if there is an actual fault in the microwave circuits.

Therefore, try a new fuse. If this blows immediately, there may be a short very near the line cord, in the controller, or a defective triac (if your oven uses a triac). Or, even a shorted oven lamp - remove and inspect the light bulb and socket.

If it does not blow, initiate a cook cycle (with a cup of water inside). If the oven now works, the fuse may simply have been tired of living. This is common.

If the fuse still blows immediately, confirm that the controller is operational by unplugging the microwave generator, power relay, and/or triac from the controller. If a new fuse does not now blow when a cook cycle is initiated - and it appears to operate normally - then one of the components in the microwave generator is defective (shorted). See the section: Microwave generator problems.

Some models have a thermal fuse as well and this may have failed for no reason or a cooling fan may not be working and the oven overheated (in which case it probably would have died while you were cooking something for an important guest - assuming you would use a microwave oven for such a thing!).

Other possible causes: bad controller power supply or bad controller chip.

Totally dead oven after repair

On some microwave ovens, there is at least one cabinet screw that is slightly longer than all the others. This engages a safety interlock which prevents the oven from receiving power if the correct screw is missing or in the wrong hole. Check the length of all the screws and locate the interlock switch behind one of the screw holes. I don't know how common this practice is but have heard of it on some Sharp models. Also see the section: Getting inside a microwave oven.

Of course, any number of other pre-existing or induced problems can result in the oven playing dead after it has been "repaired". :

Dead controller

The most common way that the controller circuitry can be harmed is by a power surge such as from a lightning strike. Hopefully, only components on the primary side of the power transformer will be affected.

- Check the primary of the power transformer - if it is open, there may be a fuse/thermal fuse underits outer insulation. If not, the transformer will need to be replaced. There is a good chance that the surge didn't propagate beyond the transformer and thus the rest of the controlled should be unaffected.
- In some cases, circuit board traces may have been vaporized (but repair may still be possible by simply jumpering across the crater). Some of these thin traces may be there specifically to act as fuses - and there may even be spares to use for just this situation!
- Assuming that the main fuse and power transformer primary checks out, then check the power supply for the controller next.
- As always, also check for bad solder connections.

If the controller power supply is working and there is still no sign of life (dead display and no response to buttons) the microcontroller chip or some other part may be bad. It could be a simple part like a capacitor or diode, but they would all need to be tested. At this point, a schematic of the controller board will be needed - often impossible to get - and replacement controller or even just the main chip may be nearly as expensive as a complete new oven.

No response to any buttons on touchpad

There can be many causes for this behavior (or lack of behavior):

- Door is not closed - on many ovens, there will be no response to any buttons - even setting the clock - unless the door is securely closed.
- You waited too long - some models (like Sharp) have a timeout. If you close the door but don't proceed to activate any functions with a couple of minutes, they will require you to open and close the door to reset their pathetic brains.
- Controller is confused - a power surge or random non-reproducible action of the universe may have resulted in the controller's program ending up in an infinite loop. Pull the plug for a minute or two to reset it.
- Defective interlock switches - this can result in the controller thinking the door is open and ignoring you.
- Faulty controller or its power supply - a power surge may have damaged the electronics. Other than checking for bad connections and obviously bad power supply components, diagnosing this will be tough without a schematic (and possibly much more).
- Touchpad or controller board contaminated by overenthusiastic cleaning - if you recently power washed the oven (or even if you only use some spray cleaner), some may have gotten inside and shorted out the touchpad or controller.
- Defective or damage touchpad - physical abuse is not a recommended technique for getting a microwave oven to cooperate. If there is any visible damage to the touchpad - the outer film is broken - it will probably need to be replaced.

Also see the section: Some of the keys on the touchpad do not function or perform the wrong action.

Oven runs when door is still open

WARNING: Needless to say, DO NOT operate the oven with the door open! While extremely unlikely, the microwave be generator could be running!

For microwaves to actually be generated with the door still open would require the failure of all 3 interlock switches. The only way this could really happen would be for the 'fingers' from the door that engage the interlocks to break off inside the oven keeping the interlocks engaged. In this case, the controller would think the door was always closed.

Where no such damage is evident, a failure of this type is extremely unlikely since power to the microwave generator passes through 2 of the 3 interlock switches. If both of these failed in the closed position, the third switch would have blown the fuse the last time the door was opened.

Another more benign possibility is that one or more fans are running as a result of either a defective sensor or normal operation to maintain air flow until all parts have cooled off.

Oven starts on its own as soon as door is closed

If the oven starts up as soon as the door is closed - regardless of whether a cook cycle has been selected, the cause could be a shorted triac or relay or a problem with the controller or touchpad.

First, unplug the oven for a couple of minutes to try to reset the controller.

If this doesn't help, put a cup of water into the oven and let it run for a minute to check for heating. (You could also note the normal sound change or slight dimming of lights that accompanies operation of the magnetron.) Much more must be enabled to actually power the magnetron so this might point more to the controller as being faulty but not always.

Also see the section: Whacked out controller or incorrect operation.

Oven works but totally dead display

If all functions work normally including heating but the display is blank (assuming you can issue them without being able to see the display), the problem is almost certainly in the controller or its power supply.

Try pulling the plug for a minute or two - for some reason the display portion of the controller may have been sent out to lunch by a power surge or alpha particle. It woudn't be the first time.

Check for bad connections between the display panel and the power supply and solder joints on the controller board.

With everything else operational, a bad microcontroller chip is not that likely but is still a possibility. If the oven was physically abused, the display panel may have fractured though it would take quite a bit of violence. In this case, more serious damage to the door seals may have resulted as well which would be a definite hazard.

Whacked out controller or incorrect operation

The following are some of the possible symptoms:

- All the display digits may have come on, EEEE or FFFF, or be displaying in Greek.
- The end-of-cooking cycle or keypress tone may be wailing away continuously. (By 'tone' I mean from the controller (not a low buzzing or humming when attempting to cook which would indicate a microwave generator power problem like a shorted magnetron).
- Pressing a button on the touchpad may result in a totally incorrect action such as entering the time resulting in the oven starting to cook. However, for the special case where pressing START results in erratic behavios, see the section: Erratic behavior.
- The oven may start cooking (or at least appear to) as soon as the door is closed. Pressing buttons on the touchpad may or may not have any effect. (This could also be a shorted triac or power relay).

First, try unplugging the oven for a couple of minutes - perhaps the controller is just confused due to a power surge, lightning strike or the EMP from a nearby nuclear detonation because it wanted attention.

If you recently cleaned the oven, some liquid may have accidentally gotten inside the touchpad or even the controller circuitry (though this is less likely). See the section: Some of the keys on the touchpad do not function or perform the wrong action.

If the oven seems to have a mind of its own - running a cycle you didn't think you programmed, are you sure a previous cook cycle was not interrupted and forgotten? Try to recreate the problem using a cup of water as a load.

Assuming this does not apply, it sounds like a controller problem - possibly in its power supply. First check the controller PCB for obvious problems like burnt components and bad solder connections. Look for bulging or leaking electrolytic capacitors. Check for AC across them - there should be little or none. (But make sure your multimeter has an internal capacitor to block DC, else it will not read AC correctly.) Bad electrolytic capacitors resulting in a large amount of ripple on one or more DC power supplies are particularly likely if there is a flickering display or chattering relay. There have been reports of bad capacitors in late model GE ovens but of course GE will want to sell you a $200+ controller board, not a 50 cent cap so don't expect this advice should you call them! but could also be the controller chip. My guess is that unless you were to find some simple bad connections or an obvious problem with the controller's power supply, the cost to repair would be very high as the custom parts are likely only available from the manufacturer.

The controller's program may be corrupted (unlikely) but we have no real way of diagnosing this except by exclusion of all other possibilities. Depending on the model, some or all operations - even setting the clock - may be conditional on the door interlocks being closed, so these should be checked. Some ovens will not allow any actions to be performed if the door has been closed for more than a few minutes - open and close the door to reset.

A controller failure does little to predict the reliability of the rest of the oven. The microwave generator circuits could last a long time or fail tomorrow. The output of the magnetron tube may decrease slightly with use but there is no particular reason to expect it to fail any time soon. This and the other parts are easily replaceable.

However, unless this oven has a lot of fancy features, you can buy a replacement (depending on size) for $100-200 so it is probably not worth fixing unless it is something relatively simple and inexpensive.

Erratic behavior

There are three different situation:

- Whenever the oven performs unexpectedly both during setup and the cook cycle, suspect the controller power supply or bad connections.
- Where problems only occur when entering or during the cook cycle, suspect a power relay or mechanical timer (if used) with dirty or worn contacts, or (less likely) the power surge from energizing the microwave generator or microwave (RF) leakage into the electronics bay affecting the controller.
- However, if erratic simply means that it doesn't heat consistently, see the section: Oven heats but power seems low or erratic.

The filter capacitor(s) in the controller's power supply may be dried up or faulty. Check with a capacitor meter or substitute known good ones. Prod the logic board to see if the problem comes and goes. Reseat the flex cable connector to the touchpad.

For mechanical timers, the timing motor could be defective or require lubrication. The contacts could be dirty or worn. There may be bad connections or loose lugs.

The primary relay may have dirty or burnt contacts resulting in erratic operation. If the oven uses a HV relay for power control, this may be defective.

If the times and power levels appear on the display reliably but then become scrambled when entering the cook cycle or the oven behaves strangely in some other way when entering the cook cycle, there are several possibilities:

- The power surge caused by the cook cycle starting is resulting in changes to the settings or else the microcontroller is not interpreting them properly. This may be due to a faulty part of bad connections in the controller or elsewhere. As with intermittent problems, a thorough search for loose ground and other connections and bad solder joints may locate the source of the difficulty.
- Microwave (RF) leakage into the electronics bay due to an faulty joint between the magnetron and the waveguide or structure failure of the magnetron may be interfering with the operation of the microcontroller. Unless the oven was dropped or 'repaired' by an butcher, this sort of failure is unlikely. If you suspect either of these, inspect the integrety of the magnetron-waveguide joint and make sure the RF gasket is in place. Unfortunately, this is sometimes difficult to pinpoint because unless there is obvious mechanical damage, the 'problem' may disappear once the cover is removed for testing. See the section: Problems with internal microwave leakage.
- On rare occasions, the main fuse may become intermittent rather than failing completely. The surge or vibration of starting can jiggle the element open or closed. It is easy to try replacing it!

Problems with internal microwave leakage

(From: Charles Godard (cgodard@iamerica.net).)

I only service Amana's, but have serviced lot's of them over the years. I've only found a few that leaked with my expensive leak detector. The most memorable was the one with the leak that was due to the copper gasket that's between the magnetron tube and the cavity. I just reformed the gasket and reseated the magnetron and that fixed the leak.

The symptom was that the Touch Pad timer lights and indicators would change while the unit was cooking. I thought I had a timer problem. I took it apart and checked for loose solder joints and even cleaned the glass touch pad contacts.

For some reason that I don't remember now, I checked for radiation with the cover off the unit and found it extremely high.

It turned out that the radiation was affecting the controller.

From the outside, with the cover on, the unit didn't leak.

Long ago, I tried one of the cheapie detectors because one of my parts supply houses suggested it, and it detected leaks on everything. After that I shelled out the bucks and bought a real detector.

(From: Matthew Sekulic (goatboy@telusplanet.net).)

I have had a similar experience with a Sanyo, similar symptoms, but with the leakage from the spot welded waveguide inside the unit. Our calibration meter showed a two watt leakage, with none escaping the outer case when attached.

(My worst case of actual external leakage was from a misaligned door at .75 watts with the probe's styrofoam spacer placed against the door, of course dropping off to near zero a few inches away. My clue in was a spark between the waveguide and the case, when I was messing with the Controller PCB.)

Some of the keys on the touchpad do not function or perform the wrong action

Touchpads are normally quite reliable in the grand scheme of things but can fail as a result of physical damage (your spouse threw the roast at the oven), liquid contamination (from overzealous cleaning, for example), or for no reason at all.

Look carefully for any visible signs of damage or spills. The touchpads often use pressure sensitive resistive elements which are supposed to be sealed. However, any damage or just old age may permit spilled liquid to enter and short the sensors. A week or so of drying may cure these problems. If there is actual visible damage, it may be necessary to replace the touchpad unit, usually only available from the original manufacturer. Also, check the snap type connector where the touchpad flex-cable plugs into the controller board. Reseating this cable may cur a some keys dead problem.

Some people have reported at least temporary improvement by simple peeling the touch pad off of the front panel and flexing it back and forth a few times. Presumably, this dislodges some bit of contamination. I am skeptical as this could just be a side effect of a bad connection elsewhere.

With a little bit of effort (or perhaps a lot of effort), the internal circuitry of the touchpad can be determined. This may require peeling it off of the front panel). Then, use resistors to jumper the proper contacts on the flex cable connector to simulate key presses. This should permit the functions to be verified before a new touchpad is ordered.

Caution: unplug the microwave generator from the controller when doing this sort of experiment!

If the problem was the result of a spill into the touchpad, replacement will probably be needed.

However, if you have nothing to lose, and would dump it otherwise, remove the touchpad entirely and wash it in clean water in an effort to clear out any contamination, then do the same using high purity alcohol to drive out the water, and then dry it out thoroughly. This is a long shot but might work.

Microwave oven does not respond to START button

While all other functions operate normally including clock, cook time, and power setting, pressing START does nothing, including no relay action and the timer digits do not count down. It is as though the START button is being totally ignored. (However, if there is a momentary response but then the oven shuts off, see the section: Erratic behavior.

If there is an alternate way of activating the cook cycle, try it. For example, Sharp Carousel IIs have a 'Minute Plus' button which will cook for one minute on HIGH. Use this to confirm the basic controller logic and interlock circuitry. If it works, then the problem may indeed be a faulty START button. If it is also ignored, then there may be a bad interlock or some other problem with the controller.

Check for bad interlocks or interlocks that are not being properly activated.

Next confirm if possible that the START touch pad button is not itself faulty. If you can locate the matrix connections for this button, the resistance should go down dramatically (similar to the other buttons). See the section: Some of the keys on the touchpad do not function or perform the wrong action. The START button does, after all, sees quite a lot of action!

Assuming it is not the touch pad, it sounds like the controller is either not sensing the start command or refusing to cooperate for some reason - perhaps it thinks an interlock is open. Otherwise, the timer would start counting. Testing the relay or triac control signal will likely show that it is not there. Check that there are no missing power supply voltages for the controller and bad connection.

Microwave generator problems

Failures in the microwave generator can cause various symptoms including:

- No heat but otherwise normal operations.
- Fuse blows when closing or opening door.
- Loud hum and/or burning smell when attempting to cook.
- Arcing in or above oven chamber.
- Fuse blows when initiating cook cycle.
- Fuse blows when microwave shuts off (during or at end of cook cycle).
- Oven heats on high setting regardless of power setting.
- Oven immediately starts to cook when door is closed.
- Oven heats but power seems low or erratic.
- Oven heats but shuts off randomly.

Most of these are easy to diagnose and the required parts are readily available at reasonable prices.

No heat but otherwise normal operation

If the main power fuse is located in the primary of the high voltage transformer rather then at the line input, the clock and touchpad will work but the fuse will blow upon initiating a cook cycle. Or, if the fuse has already blown there will simply be no heating action once the cook cycle is started. There are other variations depending on whether the cooling fan, oven light, and so forth are located down stream of the fuse.

Some models may have a separate high voltage fuse. If this is blown, there will be no heating but no other symptoms. However, high voltage fuses are somewhat rare on domestic ovens.

A number of failures can result in the fuse NOT blowing but still no heat:

- Bad connections - these may be almost anywhere in the microwave generator or the primary circuit of the HV transformer. A common location is at the crimp connections to the magnetron filament as they are high current and can overheat and result in no or intermittent contact. See the section: See the section: Testing the magnetron.

- Open thermal protector - usually located on magnetron case. Test for continuity. It should read as a dead short - near zero ohms. See the section: Testing thermal protectors and thermal fuses.

- Open thermal fuse - some ovens have one of these in the primary circuit. It may be in either connection to the HV transformer or elsewhere. Test for continuity. It should read as a dead short - near zero ohms.

- Open HV capacitor - see the section: Testing the high voltage capacitor. A shorted HV capacitor would likely immediately blow the fuse.

- Open HV diode - see the section: Testing the high voltage diode.
- Open magnetron filament - This failure may also be due to loose, burnt, or deteriorated press (Fast-on) lugs for the filament connections and not an actual magnetron problem. See the section: Testing the magnetron.
- Open winding in HV transformer. See the section: Testing the high voltage transformer.
- Defective HV relay. A few models use a relay in the actual high voltage circuitry (rather than the primary) to regulate cooking power. This may have dirty or burnt contacts, a defective coil, or bad connections
- Shorted HV diode - see the section: Testing the high voltage diode.
- Short or other fault in the magnetron - see the section: Testing the magnetron.
- Short in certain portions of the HV wiring. See the section: Testing and repairing the wiring and connections.

A shorted HV diode, magnetron, or certain parts of the HV wiring would probably result in a loud hum from the HV transformer but will likely not blow the main fuse. (However, the HV fuse - not present on most domestic ovens - might blow.)

Depending on design, a number of other component failures could result in no heat as well including a defective relay or triac, interlock switch(s), and controller.

Timer and light work but no heat, cooling fan, or turntable rotation

This means the controller thinks the oven is working but the microwave generator AND motors aren't being powered. Note that these symptoms are subtly different than just having no heat and eliminates the actual components of the microwave generator from suspicion in most cases.

(From: Bonita Lee Geniac (bgen@wdl.net).)

When the timer counts down but nothing else works, 99% of the time the lower door switch is bad or else the door is not closing fully and the latch hooks are not depressing the upper and lower switches. There is also a slight possibility that the relay or triac on the control board is not closing but those usually do not result in these particular symptoms. Most of the microswitches used in recent production microwaves are very poor quality and the silicone lubrication used by some of the manufacturers migrates into the switch contact area and makes the switch fail even faster than it should.

Fuse blows when closing or opening door

This means that the main fuse in the microwave (or less commonly, the fuse or circuit breaker for the power outlet) pops when the microwave oven door is closed or opened. This may be erratic, occurring only 1 out of 10 times, for example.

The cause is almost certainly related to either the door interlock switches or the door itself. Marginal door alignment, broken 'fingers' which operate the switches, dislocated parts in the interlock mechanism, or a defective interlock switch may result in either consistent or erratic behavior of this type.

On some ovens, this can happen at any time regardless of the control panel settings or whether the oven is in the cook cycle or not. On others, it can only happen when interrupting the cook cycle by opening the door or when initiating the cook cycle from the front panel (if the switches are in the wrong state).

The rational for this basic design - some form of which is used in virtually all microwave ovens - is that a defect in the interlock switches or door alignment, which might result in dangerous microwave radiation leakage, will produce a hard permanent failure. This will prevent the oven from being used until it is inspected and repaired.

- As noted, one of the interlock switches is actually across the power line. If the switches are activated in the wrong sequence due to a misaligned door, that switch will not turn off before the other switches turn on shorting the power line. Similarly, if its contacts are welded closed, the power line will be shorted when the other switches close.

  See the section: Testing and replacing of interlock switches.
- Inspect the door, its mounting, and the plastic 'fingers' which operate the interlock switches as well. Again, if the sequence is not correct, the power line will be shorted blowing the fuse. If the oven was dropped, then such damage is quite likely. Look for broken or dislocated parts, warpage, and other indications of problems with the door and interlock mechanism Of course, if the oven was dropped, there could be much more extensive internal damage as well.

Loud hum and/or burning smell when attempting to cook

A loud abnormal hum is an indication of a short somewhere. The sound may originate from the HV transformer vibrating and/or from within the magnetron depending on cause. There may be a burnt odor associated with this behavior:

- Shorted HV diode - see the section: Testing the high voltage diode.
- Shorted magnetron (filament to anode) or other internal fault in the magnetron - see the section: Testing the magnetron. Arcing within the Magnetron case (visible through ventilation holes in the bottom section) is usually an indication of a bad magnetron.

Note that a short on the load side of the HV capacitor will likely result in the actual wattage drawn from the power line being *much lower* than under normal conditions. Although there will be a high current flowing in the HV transformer secondary through the HV capacitor (which is what causes the hum or buz), the real power consumed will be reduced since the current and voltage will be out of phase (due to the series capacitor) and the power factor will be low. A reading on an AC line wattmeter of 300 W compared to the normal 1,200 to 1,500 W would be reasonable.

- Other short resulting from frayed insulation or wires touching in the microwave generator.
- Shorted HV transformer - see the section: Testing the high voltage transformer.

- Short resulting from burnt on food (usually) in or around the waveguide. If the odor is coming from the oven chamber, see the section: Arcing in or above oven chamber.

The following procedure will quickly identify the most likely component if the problem is not food/spills/carbon related:

(Usually a loud hum that doesn't result in a blown main fuse is caused by a short in the HV diode, magnetron, or wiring on the load side of the HV capacitor. The other items listed below would likely blow the main fuse but possibly not always.)

(Portions from: Tony (tonyb@ramhb.co.nz).)

1. Discharge HV capacitor! (If there is a short it is doubtful if it has any charge but never hurts to be safe).
2. Remove one end of the lead from the HV capacitor to the transformer.
3. Start the oven.
   - Hum gone? If so, it is the HV circuitry, go to step 4.
   - If it still hums you probably have a faulty HV Transformer. (Not uncommon.)
4. Discharge the HV capacitor again, reconnect wire and disconnect the 2 wires to the magnetron.
5. Restart oven.
   - Hum Gone? If so, magnetron is shorted. Replace or get a new oven.
   - Hum still there? If so, go to step 6.
6. You have either
   - Shorted HV capacitor,
   - Shorted HV Diode,
   - Shorted clamp diode across the HV Cap terminals (if one is present, about 30% of microwave ovens use these). (The oven will run 100% without this protection for the HV capacitor but it should be replaced if possible.)
   - Some older Panasonic ovens have a HV reed switch which can also short, but these ovens are rare now because of their age.

Arcing in or above oven chamber

There is often a simple cause:

- Arcing in the oven chamber with a normal load (a cup of water, for example), often just indicates that a thorough cleaning of the oven chamber is needed, particularly around and inside/above the waveguide cover. Any food that gets trapped here will eventually burn and carbonize resulting in a focal point for further arcing. Usually, the waveguide cover is designed to be removable without taking the (cabinet) cover off of the oven. However, burnt food and carbon often make this difficult so that some disassembly will be required. See the sections: "SAFETY" and "Getting inside a microwave oven". Clean the waveguide cover and clean inside the waveguide as well. If the waveguide cover is broken or damaged seriously, a sheet of replacement material is available from places like MCM Electronics. Trim to fit with a pair of heavy duty scissors, metal snips, or a paper cutter. The oven will work fine without it but replacement will prevent contamination of the waveguide with food vapors or splatters which can lead to more expensive damage. Take extra care to cover all food (which you should do anyhow) until the waveguide cover is replaced.

- Arcing at the roof of the oven chamber on the waveguide cover may be due to carbonized food there. Or, if the cover is missing, check for pieces inside the waveguide that can be arcing. How this would happen is a mystery but apparently it can. :)

- Any sharp metal edges may also result in arcing or sparking. However, the only way such damage could occur as part of the oven (not added knives or forks!) would be through physical abuse.

- If your oven uses a stirrer above the oven chamber (no turntable), it may be stuck. The result will be an uneven distribution of microwave energy and localized heating, arcing, and possibly melting plastic or metal.

- Flashing and sparking may also result from the stirrer/fan blades contacting the metal surrounding it due to the motor/bearings becoming loose or dislodged.

More on the waveguide cover and cleaning

That cover is made of an insulator transparent to microwaves, usually mica, not a metal. The material can be obtained from places like MCM Electronics which you then cut to size with a pair of scissors or a paper cutter.

First, completely clean below, above, inside, and whatever of the cover material is remaining. All traces of carbon and burnt on food must be removed. In particular, you need to clean inside the waveguide above the inside top of the oven as well.

Then run the oven (with the waveguide cover removed, if necessary) to verify that there are no other problems (there probably are none).

Sometimes, you need to remove the outside metal cover in order to remove the waveguide cover. There may be little plastic pins or snaps which tend to get gummed up with burnt food and may be difficult to pry off from inside the oven. If you do need to remove the metal cover, jot down the locations of each of the screws (they are not always all alike) and stay away from everything but the waveguide cover itself (especially the high voltage components!).

That waveguide cover is not essential to the operation of the oven but it does prevent food from entering the waveguide and getting trapped there.

Fuse blows when initiating cook cycle

The fuse may only blow when actually attempting to cook but depending on design, triacs and/or door switches may always be live and may result in a blown fuse at any time when plugged in or when the door is opened or closed.

The following can cause the fuse to blow (in approximate order of likelihood):

- Defective interlock switches or misaligned door. At least one of the interlock switches is across the power line and will blow the fuse if not activated in the correct sequence. See the sections: "Fuse blows when closing or opening door" and "Testing and replacing of interlock switches".
- Shorted HV capacitor. See the section: Testing the high voltage capacitor.
- Shorted HV diode (see note below). See the section: Testing the high voltage diode.
- Shorted magnetron (filament to anode - see note below). See the section: Testing the magnetron.
- Defective triac (shorted or partially shorted). See the section: Testing and replacing the triac.
- Old age or power surge. Fuses sometimes blow for no apparent reason.
- Defective HV transformer (shorted windings. See the section: Testing the high voltage transformer.
- Shorted wiring due to vibration or poor manufacturing quality. See the section: Testing and repairing the wiring and connections.

Note that a shorted magnetron or shorted HV diode - which you would think should blow the fuse - probably will not do so because current will be limited by the impedance of the HV capacitor (assuming it is not shorted as well). However, there will likely be a loud hum from the HV transformer as it strains under the excess load. Such a sound in conjunction with no heat is a likely symptom of a shorted magnetron or HV diode. If your oven has a separate high voltage fuse - somewhat rare in domestic ovens - it may certainly blow due to a fault in any of the HV components.

Fuses also die of old age. The types of fuses used in microwave ovens are subjected to a heavy load and you may find that all that is needed is to replace the fuse with one with equivalent ratings. (but check for shorts first). There could be an intermittent problem as well which will only show up at some random time in the future. A poorly timed power surge (as opposed to the well timed variety) could also weaken the fuse element resulting in eventual failure.

The fuses used in microwave ovens are usually ceramic 1-1/4" x 1/4" 15 or 20 A 250 V fast blow type. Replace with exactly the same type and rating.

Another possible cause of a blown fuse is a partially bad triac. Some ovens use a triac rather than a relay to control the main power to the high voltage transformer. One type of failure of a triac is for it to be totally shorted causing the oven to come on whenever the door is closed. Alternatively, the gate may be defective preventing the triac from ever turning on. A third, and most interesting possibility, is that one half of the triac is bad - shorted or open, or doesn't turn on or turn off reliably. Recall that a triac is in effect a pair of SCRs in parallel in opposite directions. If one side is defective, the main fuse will blow due to transformer core saturation since the triac will act as a rectifier and transformers really do not like DC.

See the chapter: "Testing and Replacement of Components" for more information on this and similar problems.

Fuse blows when microwave shuts off (during or at end of cook cycle)

This could be due to a number of faults including shorting wires or defective relay. However, a common cause that might not be obvious is that the triac used to switch power to the high voltage transformer is faulty. What is probably happening is that only one half of the triac (recall that a triac is controlled for both polarities of the line voltage/current) is turning off completely resulting in DC to the HV transformer, core saturation, and excessive current which blows the fuse. Drive to the triac could also be marginal but the bad triac is more likely.

Exactly how a bad relay could result in these symptoms unless it was actually arcing and shorting is unclear. However, there is anecdotal evidence to suggest that inspecting the relay contacts and cleaning them if necessary may cure it in some cases.

The following description applies directly to some GE and Hotpoint models. Modify it accordingly for your oven. Depending on model, the triac may be located on the control board or mounted directly on the chassis.

(From: John Gallawa (john@microtechfactoryservice.com).)

I have seen exactly this problem; and I've seen it baffle many a repair shop. It is likely that the triac on the 'Power Control Board' is breaking down. This is a fairly common problem in GE and Hotpoint models that use this board.

You can usually confirm the problem by setting the oven to a lower power level, say "medium," and heat a cup of water. You will probably hear a 'thump!' each time the magnetron cycles on. This is an indication of a weakened triac.

Replace the triac (Q1) with either of the following: ECG 56010, or SK 10265. Finally, replace the line fuse, install the outer cover, and test the oven for proper operation.

The only other alternative is to replace the board. The cost used to be pretty reasonable, but now it's gotten expensive - probably about $80.00.

The triac is probably located beneath a red plastic guard on the power control board. Its designation is usually Q1.

(From: John Montalbano (jrmont@iquest.net).)

The microwave oven in my General Electric JHP65G002AD cooking center blew its 15 AMP fuse each time the timing cycle expired. Replacing the triac GE Part number WB27X5085 ($65.00 from GE) with a new NTE56014 ($13.00) solved the problem.

(From: Les Bartel lbartel@veribest.com).)

I had the exact same symptoms on my GE microwave. I replaced the triac with a $3 15 amp off-the-shelf triac and it has been working for several years since.

See the chapter: "Testing and Replacement of Components" for more information on triac testing though replacement is probably the only sure test.

Oven heats on high setting regardless of power setting

Power levels in a microwave oven are controlled by cycling the microwave generator on and off with a variable duty cycle - kind of like slow pulse width modulation. For 'HIGH', it runs continuously; for low, it may run 10% on and 90% off; other settings are in between.

When the oven always seems to be stuck at high power, it is likely to be due to one of two possible causes - a faulty relay or Triac, or controller. The relay or triac may have failed in the on state. This will probably show up with ohmmeter tests (with the oven unplugged!) but not always.

Replacements should be readily available. If the problem is is the controller, it will be more difficult to diagnose as schematics for the controller are usually not readily available. However, it could be something simple like a bad connection or dirty connector.

Oven heats but power seems low or erratic

Some considerations are how old the oven is and did the problem happen suddenly or did it just gradually weaken over the years.

First, are you sure the problem is real? Perhaps you are just a little less patient than you used to be. Perform a water heating test or try to pop a bag of popcorn using you usual time setting. See the section: Testing the oven - the water heating test.

- If you are subject to brownouts or are running on your own generator, the line voltage may be low. Power output is quite sensitive to the AC input - there is no regulation. A 10% drop in line voltage is likely to reduce microwave power output by more than 20%.
- Magnetrons, like other vacuum tubes, can weaken with age and use. An oven that sees daily use may indeed weaken over the course of several years. It is unlikely that any other electronic components could change value in such a way as to significantly affect power output. However, a failure of the controller or sensor (if you have one) could result in short cycling.

  Testing on HIGH will eliminate this possibility. Make sure the magnetron is powered continuously and it is not cycling. You can often tell by listening for the relay clicks and/or by observing the oven light/other lights dimming as the magnetron kicks in. 50% power should result in approximately equal on and off times.
- If you run the oven on HIGH, can you tell if it is actually heating continuously or rather it thinks you want LOW? Many microwave ovens make a clicking sound as they use a relay to switch microwave power on and off - check if you can hear this. Alternatively, lights on the same circuit or the oven light may dim slightly when the magnetron kicks in. There should not be any cycling on HIGH - the microwave power should stay on continuously while it is cooking. If it is cycling, there may be a problem with the controller or you may unknowingly be in a low power mode - check it.
- Mechanical problems are also possible. Where a spinning paddle wheel is used to 'stir' the microwave energy (often where there is no turntable), its failure to rotate can result in hot and cold spots. Thus, you may see an unexplained variation in cooking times. The paddle is often accessible by unclipping a plastic cover above the oven cavity. Check for bearing failure, binding, broken or lose belt if direct driven, etc. Note that some are rotated by air flow from the cooling fan and require that cover to be in place to rotate. Therefore, it is not really possible to inspect for correct operation with the cover removed. However, you can put a microwave power indicator (NE2 neon light bulb with its leads twisted together) in the oven (with a cup of water for a load) and observe it through the window. You should see a periodic variation in intensity as the paddles do their job.
- There could be intermittent connections to the magnetron filament, thermal protector, or elsewhere. But, these would likely show up as erratic operation - no heat at all sometimes - not just a weak oven.

  Inspect and clean and tighten (if necessary) all connections in the microwave generator including the magnetron filament, HV transformer, HV Diode, HV capacitor, and thermal protector. Be sure to unplug the unit first and discharge the HV capacitor before touching anything!
- The thermal protector may be intermittent. Test by clipping a light bulb across it or monitoring with a multimeter on AC voltage. See the section: Testing thermal protectors and thermal fuses.

Oven heats but shuts off randomly

Everything operates normally, but the oven shuts off after varying amounts of time. This could be a faulty magnetron, bad cooling fan (or just built up dust and grime block ventilation grilles), bad thermal protector, faulty controller, some other intermittent component, or bad connections.

- If resetting it allows cooking to resume immediately, if even for a few seconds, I would not suspect the magnetron or thermal problem as no cool down time is required. It could be bad connections in the controller or elasewhere, a marginal door interlock switch, or a controller problem. Jiggle the door to see if this will cause it to shut off.
- If the magnetron was overheating, you would not be able to resume cooking until it cooled and the thermal protector reset. If it just stopped working (i.e., the filament opened), everything would appear normal but there would be no heating. If the magnetron were shorting, there would likely be a loud hum associated with the periods where there was no heat.
- If it is not possible to resume cooking for a few minutes indicating that something needs time to cool off, then the magnetron could be faulty but check for the obvious cooling problems first: blocked or dirty ventilation grill. Determine if the magnetron cooling fan is operating by listening for its sound or looking through the ventilation opening in the back of the oven. If it is not, there could be a broken or weak belt, gummed up or lack of lubrication, other mechanical problems, a bad motor, or bad connections.
- Extremely high power line voltage may also result in overheating on a poorly designed or oven where the components are marginal.
- Make sure the stirrer fan is turning normally. Should it gets stuck, some models may sense this and shut down/restart.

Oven makes (possibly erratic) buzzing noise when heating

Assuming operation is normal otherwise, this is most likely either a fan or other motor vibrating on its mounts, fan blades hitting something, or some sheet metal or the high voltage power transformer laminations vibrating. There may be something stuck under the turntable or above the waveguide cover interfering with the stirrer.

Something may have loosened up with age and use.

If the noise is caused be simple vibrations, no damage is likely to result. However, if the main cooling fan is on its way out and it stops or gets stuck, parts will overheat quite quickly at which point the oven will shut down (hopefully) and there could be damage to the magnetron or other components. Therefore, at least identifying the cause is probably a good idea.

The solution may be as simple as tightening a screw or weging a shim between two pieces of vibrating sheet metal.

Oven light does not work

If the oven light no longer works, believe it or not, a burned out light bulb is likely.

You would think that something like replacing a light bulb would be trivial and self evident. Unfortunately, not always so with microwave ovens. Light bulbs may be typically located in any of 3 places:

1. Oven chamber - it may be behind a mesh grill requiring a screw or snap to be removed. This is the easiest.
2. Rear - the bulb may be in a recessed compartment accessible by removing a screw or two on the back of the oven.
3. Inside - it may be behind a non-removable grille requiring the removal of the cover.

These are typically not your usual vanilla flavored appliance bulbs either.

Bad connections are also possible but not that likely.

Fans or turntables that do not work

There are up to 4 motors in a microwave oven:

- Magnetron cooling fan - always present.
- Mechanical timer (on inexpensive non-touchpanel or older units).
- Turntable.
- Convection air circulation (combo units only).

When any of these do not operate properly, the most likely causes are:

- Gummed up lubrication/dry bearings. Check for free rotation of the affected part(s). Clean and lubrication as needed. Also confirm that there are no other mechanical problems (e.g., turntable improperly installed).
- Loose or broken belt. Confirm that belt is properly installed. Test to determine if it is worn and flabby - stretch it by about 25%. It should return to its relaxed length instantly. Clean and/or replace if needed.
- Bad motor. Disconnect one wire and check for continuity with an ohmmeter. If open, winding is bad but check for break at terminal which you can resolder.
- Bad thermostat. Where a fan only runs when the oven is hot as in a microwave/convection oven, the thermostat or controller could also be at fault. Locate the thermostat and jumper across its terminals with power off. Plug the oven in and see if the fan now runs all the time or at least when the appropriate mode(s) are entered.
- Bad connections - trace wiring and check continuity (unplugged, capacitor discharge) to motor terminals.

Note that the opposite problem - a turntable and/or fan that runs *after* the cook cycle is completed may be normal for your oven. This is a "cool-down" function designed to allow the heat to equalize or possibly added by the company's legal department to reduce the number of lawsuits due to stupidity. :)

What to do if the door handle breaks off

Usually this happens at the places where the handle is screwed to the door.

I would NOT recommend making the repair in any manner that compromises the shielding properties of the door. (I have visions of someone using 1/2" stove bolts through the door and handle which would definitely be a bad idea). Anything that penetrates the door seal is a potential hazard - likely a very small one but it is not worth the risk.

Therefore, I would recommend staying with repairs that can be made totally externally unless there is no possibility of a change to the integrity of the door. For example, replacing the screws with similar sized screws that gripped better or using filler to reconstruct or strengthen the threaded holes would be acceptable.

Plastic is generally tough to glue where a strong bond is needed and where the joint is subject to abuse. However, depending on the type of plastic, one or more of the following may work: semiflexible adhesive like windshield sealer, plastic cement (the kind that fuses the plastic, not model cement), Duco cement, PVC (pipe) cement, or even superglue (though it seems not all brands are equally effective). Make sure the surfaces to be glued are perfectly clean (remove any residual library paste if you tried that!) and provide a means of clamping the pieces until the bond sets up (adhesive tape and/or rubber bands may be all you need). Consider providing some reinforcements around the joint (i.e., plastic splints or sisters depending on your profession) for added durability.

Replacement door handles and/or entire doors may be available from the manufacturer of the oven. Replacements for a few Panasonic models are even stocked by

MCM Electronics (and no doubt other places as well).

(From: John Gallawa (john@microtechfactoryservice.com).)

Here are the door disassembly instructions from the Amana service manual. Many others are similar:

1. Pry out the inner door trim with a small screwdriver on the latch side of the door.
2. Remove two screws securing the latch assembly and door handle to the outer panel (this may be all that's needed to replace the handle).
3. Remove six screws and release 4 spring fingers that secure the choke to the outer panel.

WARNING: A microwave leakage test must be performed any time a door is removed, replaced, disassembled, or adjusted for any reason.

Crack or other damage to door window

> "My microwave oven has a crack in the glass of its door. Is this safe to continue using or should I get it fixed? Will there be any radiation leakage?"

So you were throwing roasts at the oven again, huh? :-)

If the metal screen/mesh is behind and separate from the glass, there is no danger. In this case, the function of the glass is mostly cosmetic and a small crack should not be a problem.

However, if the screen is inside the glass and now broken as well, there could be microwave leakage. Even if it is not actually broken at this time, future failure is possible. Therefore, the glass panel or entire door should be replaced.

Also, any break large enough to allow something to touch the metal screen is a hazard because during cooking, there could be shock hazard due to microwaves inducing current in the screen. And, poking something metallic through the screen would make is susceptible to microwave pickup as well.

However, damage to the inner plastic is probably not a cause for concern as that is only there to keep the screen and inside of the door glass clean.

Repairing damage to the oven interior

If spilled food - solid or liquid - is not cleaned up soon after the oven is used, it will tend to harden and carbonize. Not only will this be much more difficult to remove, but hot spots may develop and result in possible sparking, arcing, and damage to the interior paint.

If this happens in the vicinity of the mica waveguide cover, it may be damaged as well. In addition, sometimes splatters may find their way above the waveguide cover and cause problems above the roof of the oven chamber in the waveguide.

Needless to say, clean up spills and food explosions as soon as possible. Not only will it be easier, the chance of future expensive problems will be minimized.

To prevent arcing and sparking, the interior needs to be smooth. Sharp edges and hard carbon in particular creates places where electric field gradients can become great enough to cause problems. Thus the warning not to use any metal utensils in a microwave.

Once damage occurs - paint blisters and peels, or totally hardened impossible to remove carbon deposits - more drastic action is called for:

- Assuming cleaning does not work on the carbon - even after repeated attempts, carefully scrape it off with a blunt knife or other suitable tool. This will probably damage the paint. Use fine sandpaper to completely smooth out the metal and feather the edges of the paint in the immediate area. Until you can obtain paint, the oven will work fine but since the chamber is made of sheet steel, rust will set in eventually. So, do paint it.

  Special microwave oven cavity paint is available but any common gloss enamel will work just as well (and costs about 1/10th as much). Unplug the oven as paint solvent is generally flammable. Use touch-up paint with a small brush (recommended) or spray paint (be careful to mask off all but the immediate area). Allow at least 24 hours to dry with the microwave oven door OPEN so all the solvent has evaporatedf. The typical color is beige, almond, or some other form of off-white - just match it to your oven (if you care). While I have never heard of problems caused by these non-approved paints, it's always a good idea to test first in an inconspicuous location to be sure there are no surprises when power is applied. Test by putting a cup of water in as a load and running for a minute or so on HIGH. The area where the new paint has been applied should not be any warmer than other areas. Of course, there should be no smoke or six foot flames. :) But the odor from petro-chemical solvent-based paints may linger for some time and could be quite objectionable in the vicinity of food. Once the paint is dry to the touch, a blow-dryer on low heat (NOT a heat gun!) applied to the newly painted areas may be used to speed this along. Running the oven on the lowest setting should help as well, as the fan will circulate air throughout. Make sure there is a water or other load in the oven when doing this! Also, putting a container of used coffee grounds in the oven overnight for several nights should help clear the odor.

  As noted, damaged paint is often a symptom of other problems, most likely due to debris causing hot spots. If around the waveguide cover, there may be gummed up food trapped under the cover. If it occurred along the turntable track, the turntable wheels themselves may be full of carbonized food causing heating and/or arcing as they rotate on the bottom paint. Any of this will destroy the new paint if not thoroughly cleaned first.

- If the waveguide cover is damaged seriously - such that it no longer will prevent splatters from entering the waveguide, obtain replacement material, cut to fit. Leaving it larger than necessary is fine as well. Use a suitable bit in a hand drill to make holes in the mica for the mounting screws or plastic snaps.

  Alternatives to mica which can stand the elevated temperatures in a microwave oven may also be acceptable. Possible choices include plastic or fiberglass laminate but not all materials will allow microwaves to pass without some heating - check it out. Heat a cup of water and the candidate material on high for a couple of minutes. If the material doesn't heat up, it should be fine. Of course, it must also not have any metal coating (don't use a piece of one of those 'browning disks' :-). Mica is also non-flammable which is may not be the case with other materials.

- If the interior of the door is damaged seriously such that either it will not longer seal around the edge properly or that the mesh screening is breeched, a replacement will be required to assure continued safety with respect to minimizing microwave emissions.

Microwave oven cavity paint, waveguide cover mica sheets, and even some replacement doors are available from the parts suppliers listed at the end of this document. For most ovens, parts like doors will need to be obtained direct from the manufacturer, however.

Microwave/convection oven problems

In addition to the microwave components, these ovens also include an air circulating fan and an electric heating element as well as a temperature sensing themister. Any of these can fail.

- A convection oven which shuts down after a couple of minutes during the preheat cycle with the temperature display (if any) stuck at LOW (even though the oven is hot when opened) may have a bad thermistor temperature sensor.

- The overtemperature protection sensor (rather than the normal temperature sensor) is shutting the oven down. The termister will usually be accessible after removing the oven cover. It will be located centrally just above the oven ceiling duct or elsewhere in the convection air flow. It is a two terminal device that may look like a tiny resistor or diode and may be mounted on a metal header fastened with a couple of screws. Remove and test with an ohmmeter. An infinite reading means it is bad. As a test, jumper a 50 K ohm potentiometer in place of the thermistor. During preheat, as you lower the resistance of the pot you should see the temperature readout climb. The oven will then indicate READY when the simulated temperature exceeds the setpoint. Replacement thermistors are available from the oven manufacturer - about $20. Cheaper alternatives may be possible but you would need to know the exact specifications and it is probably impossible to obtain this information.

  Also see the section:

- Sensor problems, below.

- If the convection preheat cycle never completes and the oven is cool when opened, then either the heating element is bad (test with an ohmmeter) or the relay controlling the heating element or the controller itself is bad. If the circulating fan runs off of the same relay and it is operating, then the problem must be the heating element.

- The heating element will be either a Calrod type (GE trade name?) which is a steel tube enclosing a Nichrome wire coil embedded in ceramic filler or a coiled Nichrome element strung between ceramic insulators. The former is probably only available from the oven manufacture, though it is worth trying an appliance parts distributor or a place like MCM electronics first. It may be possible to find a replacement Nichrome coil and form it to fit. Make sure the wire gauge and length are identical.

- The circulating fan is probably driven by a belt, which may break or deteriorate. Inspect the belt. If it is loose, cracked, or does not return to its normal length instantly after being stretched by 25% replace it. Check the fan motor and fan itself for adequate lubrication. Check the fan blades for corrosion and damage.

Sensor problems

Fancier microwave or microwave/convection ovens include various probes that can be used to shut off the oven when the food is supposedly done or maintain it at a preset temperature.

A problem with a sensor, controller, or wiring, may result in incorrect operation (never getting past 'preheat' or not terminating a cook cycle) or in a display of 'EEEE', 'FFFF', ERROR, or something similar:

(From: Wilton Itamoto (witam40231@aol.com).)

> "The 'FFFF' display is a common problem in older Panasonic convection ovens. The problem is the temperature sensor thermostat located on the top rear of the oven. This is the convection temp. sensor for the correct oven temperature. Replacing this open sensor will correct the problem."

When problems develop with these automatic features, the sensor and the probe cable are the primary suspects. However, it is possible that the electronic circuitry could also be affected by a damaged or defective probe unit.

- Check for bad connections where the probe plugs in as well as broken wires inside the cable particularly near the ends where it gets flexed.

- Temperature probes may use a thermistor similar to one that controls the convection portion of a microwave/convection oven. Steam/humidity probes may also behave similarly.

- If you have never tried the probe before, check your users manual. It may only be active in certain modes, etc.

The best test of the probe unit is to substitute a known good one. Of course, this is generally not convenient.

- There should be some resistance when measuring between the signal conductors of the probe cable. It may be high (hundreds of K ohms) but probably should not be open. A very low value (a few ohms or less) might indicate a short in the cable or sensor.

- See the section: Microwave/convection oven problems for a discussion of thermistors. Testing to determine if the controller is responding to the input from the sensor can be done in a similar manner except that access must be from inside the electronics bay while the oven is running (the probe normally plugs in inside the oven chamber). Substitute a fixed or variable resistor and see if you can get the oven to shut off (or stay on) as a function of resistance. CAUTION: Don't forget to put a cup of water in as a load if you are testing microwave operation.

If the resistor test determines that the controller is responding, than a bad probe unit is likely.

If the probe checks out or substituting a known good one makes no difference in behavior, look for corrosion or other deterioration of the socket in the oven chamber as well as bad connections. Faulty circuitry in the controller is also possible.

- Back to Microwave Oven Repair FAQ Table of Contents.

Testing and Replacement of Components

Please see Typical Microwave Oven Electronics Bay for parts identification.

Testing the oven - the water heating test

The precise number of degrees a known quantity of water increases in temperature for a known time and power level is a very accurate test of the actual useful microwave power. A couple of minutes with a cup of water and a thermometer will conclusively determine if your microwave oven is weak or you are just less patient (or the manufacturer of your frozen dinners has increased their weight - sure, fat chance of that!)

You can skip the heavy math below and jump right to the final result if you like. However, for those who are interested:

- 1 Calorie (C) will raise the temperature of 1 gram (g) of liquid water exactly 1 degree Centigrade (DegC) or 9/5 degree Fahrenheit (DegF).
- 1 Calorie is equal to 4.184 Joules (J) or 1 J = 0.239 C.
- 1 Watt (W) of power is 1 J/s or 1 kW is 1000 J/s.
- 1 cup is 8 fluid ounces (fl.oz.) which is 8 x 29.57 g/fl.oz. = 236.6 g. (For Avoirdupois ounces, use 28.35 g.)
- 1 minute equals 60 s (but you know this!).

Therefore, in one minute, a 1 kW microwave oven will raise the temperature of 1 cup of water by:

```
T(rise) = (60 s * 1000 J/s * 0.239C/J * (g * DegC)/C)/(236.6 g) = 60.6 °C.
```

Or, if your prefer Fahrenheit: T(rise) = 109.8 °F.

To account for estimated losses due to conduction, convection, and imperfect power transfer, I suggest using temperature rises of 57 DegC and 135 DegF.

Therefore, a very simple test is to place a measured cup of water in the microwave from the tap and measure its temperature before and after heating for exactly 1 minute on HIGH. Scale the expected temperature rise by the ratio of the microwave (not AC line) power of your oven compared to a 1 kW unit.

Or, from a Litton microwave handbook:

- Heat one Liter (L) of water on HIGH for 1 minute.
- Oven power = temperature rise in DegC multiplied by 70.

Use a plastic container rather than a glass one to minimize the needed energy loss to raise its temperature by conduction from the hot water. There will be some losses due to convection but this should not be that significant for these short tests. For the ultimate in accuracy (as these things go), put the water in a styrofoam cup, invert another styrofoam cup over it, and poke your thermometer through it.

(Note: if the water is boiling when it comes out - at 100 DegC or 212 DegF, then the test is invalid - use colder water or a shorter time.)

The intermediate power levels can be tested as well. The heating effect of a microwave oven is nearly linear. Thus, a cup of water should take nearly roughly twice as long to heat a specific number of degrees on 50% power or 3.3 times as long on 30% power as on full power. However, for low power tests, increasing the time to 2 minutes with 2 cups of water will result in more accurate measurements due to the long period pulse width power control use by microwave ovens which may have a cycle of up to 30 seconds.

Any significant discrepancy between your measurements and the specified microwave power levels - say more than 10 % on HIGH - may indicate a problem. (Due to conduction and convection losses as well as the time required to heat the filament of the magnetron for each on-cycle, the accuracies of the intermediate power level measurements may be slightly lower).

See the section: Oven heats but power seems low or erratic.

Testing the main fuse

Where the oven is dead or mostly dead, the main fuse is the place to start:

- UNPLUG THE OVEN and locate and remove the main fuse. It will usually be a 1" x 1-1/4" ABC ceramic type directly in-line with the Hot (black wire) of the power cord.
- Test it with an ohmmeter - the reading should be zero ohms.
  - If it is blown, suspect problems with the interlock switches, high voltage capacitor, or high voltage wiring.
  - If it is good but the oven makes a loud humming sound when you attempt to cook, suspect the magnetron or high voltage diode.

Testing and replacing of interlock switches

With the oven unplugged, put an ohmmeter across the AC input just before the interlocks (but beyond the power relay or triac if it precedes these). Open and close the door slowly several times - there should be no significant change in resistance and it should be more than a few ohms. If it approaches zero while opening or closing the door, the interlock switches and door alignment should be checked. (You may need to disconnect one side of the transformer primary since its resistance is a fraction of an ohm. Refer to the schematic pasted inside the cover.)

Replace with switches having a precisely identical fit and equal or better electrical specifications (terminal configuration, current rating). When removing the old switch make a note as to where each wire goes. Check the embossed marking on the old switch - don't depend on location as your replacement might just have a different arrangement. Make sure the new switch aligns correctly with the actuating mechanism and then check for correct electrical operation with an ohmmeter before applying power.

Even slamming the door really hard has been known to knock an interlock switch out of position, resulting in breaker tripping at the electrical service panel whenever the microwave oven door was closed. (Another reason to stay calm after accidentally nuking that bagel for 5 minutes on HIGH!) So if there was some kind of "event" after which the microwave failed, check the interlock mechanism first - a switch may just need to be popped back into place.

Making measurements inside microwave ovens

WARNING: In general, I DO NOT recommend making any sorts of measurements on the high voltage components of a live microwave oven. I only include this section for those who really want to know the details.

You may be temped to break out your Radio Shack DMM and start poking away inside a live microwave oven. DON'T! This isn't like a CD player! Most of the time, no measurements of any kind on the oven while it is operating will be needed to identify and correct the problem. However, where this is not the case, here are some guidelines to a long life:

WARNING: ALWAYS pull the plug and discharge the HV capacitor BEFORE doing anything inside! Never be tempted to make any changes of any kind while the oven is on - not even if your meter is being consumed by 5 foot flames! First, pull the plug and discharge the HV capacitor!

- High voltage - DON'T even think about this unless you have a proper high voltage probe or meter, or a proper microwave oven tester - AND KNOW HOW TO USE IT SAFELY. Even professionals have been killed performing measurements of this type using proper equipment! Luckily, current measurements can provide enough information to help make a diagnosis.

  WARNING: The high voltage components inside a microwave oven are at a NEGATIVE potential with respect to the chassis. DO NOT be tempted to interchange the probe and ground wire if you are using a high voltage probe on a meter with a POSITIVE input (e.g., for testing CRT HV) and no polarity switch! The ground cable doesn't have anywhere near the required insulation. Get the proper equipment!

  One thing you can do relatively safely is to connect a Variac directly to the primary of the HV transformer. With this set at a MAXIMUM of 10 percent, the voltage on the filament terminals of the magnetron should read from -150 to -250 V with respect to the chassis. A scope can also be used if it has a proper 10:1 probe as long as you aren't tempted to turn up the Variac any higher! The scope waveform should be close to a sinusoid with its positive tips at 0 V. Such reduced voltage tests won't identify problems that only occur at full voltage, however.

- Magnetron current - Place a 10 ohm 10 watt resistor in series with the HV diode cathode and ground. Measure the voltage drop across this resistor. Sensitivity will be 10 V/A. Normal anode current is around 300 to 400 mA for a typical oven. This will be -3 to -4 VDC across the 10 ohm resistor with respect to chassis ground. SET EVERYTHING UP AND THEN STAND BACK and don't forget to DISCHARGE the HV capacitor after making the measurement:

  - If it is around this range, the magnetron is probably fine.
  - If it is very low or 0, magnetron is bad or HV is not working. Note that a shorted as well as open magnetron also results in no current. If the magnetron is shorted, it bypasses all current to ground. If the magnetron is open, the HV capacitor charges up and then there is no more current through the HV diode (but there will be an initial transient).
  - If it is much too high (whether fuse blows or not), capacitor is shorted.

(From: Michael Caplan (cy173@freenet.carleton.ca).)

A properly conducting magnetron will load down the HV power supply. If the magnetron is non-conducting, the voltage remains high.

The power supply will produce 3,500 to 4,000 volts DC, or more, open circuit (as when the oven is first turned on and the magnetron filament/cathode is not fully heated). With full conduction by the magnetron, the HV drops to between 1,800 and 2,100 V. Weak magnetrons conduct somewhat, but the HV remains well above the 2,100 V. (The voltages vary with design and model, but the magnitude of the change is the key.)

I check the HV using my 30 kV HV probe with a DMM, measuring between the magnetron filament connectors (either one) or at another equivalent point, and case ground. (Again, depends on the circuit, but I think this is a common configuration.) The HV at the magnetron filament is negative to ground.

Testing the high voltage components

WARNING: First, with power disconnected, discharge the high voltage capacitor. See the section Safe discharging of the high voltage capacitor.

Assuming the oven passes the above test for interlocks and door alignment, the triac (if used) may be defective. There could also be a wire shorting to the chassis. However, the most likely problems are in the microwave generator.

An ohmmeter can be safely used to quickly determine if the capacitor, HV diode, or magnetron are a dead short (as well as for an open magnetron filament).

Use an ohmmeter to test the diode and capacitor. While connected in circuit, the resistance in at least one direction should be several M ohms. (Try it in both directions, use the higher reading). Test the magnetron from the filament to chassis - it should be high in at least one direction. Test the filament for continuity - the resistance of a good filament is close to 0 (less than 1 ohm).

Where the capacitor and diode are combined into one unit, it should be possible to test each component individually. In some cases, it may also be possible to replace only the one that is found to be defective or make up a substitute HV cap/diode assembly from individual components if the combined unit is excessively expensive or no longer available.

These may be considered to fail/no conclusion tests - they can definitively identify parts that are bad but will not guarantee that they are good. Parts may test ok with no voltage applied but then fail once operated in-circuit. Connections may open up when they heat up. The magnetron may short out when full voltage is applied.

Don't overlook the wiring as no heat or erratic operation can result from simple bad connections!

An alternative way of determining if the problem is in the control circuits (triac, relay, wiring) or microwave generator (HV transformer, HV capacitor, HV diode, magnetron, wiring, etc.) is to connect the HV transformer primary directly to a line cord and plug. Tape the removed wire lugs to prevent shorts.

Plug the transformer cord into a switched outlet strip which includes a fuse or circuit breaker.

Put a cup of water into the oven cavity to act as a load.

- Power the oven via its line cord. Initiate a cook cycle. It should go through the normal cycle (of course no heat) without blowing the fuse or any unusual sounds. If there is a problem in this case, something in the controller or its wiring is shorted.
- Now, initiate a 1 minute cook cycle on HIGH and with the oven running, switch on the HV transformer.
    - If the transformer or other HV components are faulty, the outlet strip fuse will blow or circuit breaker will trip. Or, if a lamp is plugged into the outlet strip at the same time, it will likely dim significantly due to the heavy load before the fuse or breaker cuts out.
    - If the problem is with the triac or its drive, the oven will now heat normally. When the cook cycle is near its end, switch off the outlet strip. Check the water's temperature.

More complete information on testing and replacing the individual components is provided in the next few sections.

Testing the high voltage diode

WARNING: First, with power disconnected, discharge the high voltage capacitor. See the section Safe discharging of the high voltage capacitor

The HV diode can fail shorted (most likely) or open. It is not likely for there to be anything in between as so much heat would result that the diode would not remain that way for long.

- A shorted HV diode will likely result in a loud hum from the HV transformer when a cook cycle is initiated. The main fuse will probably not blow. However, note that the actual wattage drawn from the power line will probably be *much lower* than under normal conditions. Although there will be a high current flowing in the HV transformer secondary through the HV capacitor (likely causing a loud hum or buzz), the real power consumed will be reduced since the current and voltage will be out of phase (due to the series capacitor) and the power factor will be low. A reading on an AC line wattmeter of 300 W compared to the normal 1,200 to 1,500 W would be reasonable.
- An open HV diode will result in AC instead of DC across the magnetron with a peak negative value (the only one that matters) about 1/2 of what it should be. The result will likely be little or no detectable heat but no other symptoms.

The resistance measured across the leads of the HV diode should be greater than 10 M ohm in at least one direction when disconnected from the circuit. However, the HV diode is composed of multiple silicon diodes in series to get the voltage rating. Its forward voltage drop will therefore be too great (6 V or more) for a DMM to produce a definitive answer as to whether it actually works as a rectifier.

The HV diode can be tested with a DC power supply (even a wall adapter of at least 12 or 15 V output), series resistor (to limit current), and your multimeter. This will determine proper behavior, at least at low voltages.

The following is the schematic of a simple HV diode tester:

```
              240 ohms, 1 W
   + o-----------/\/\---------+------------o +
                              |
                            __|__ HV       Good:  6 to 10 V
 15 VDC                     _\_/_ diode    Shorted: 0 to 2 V
                              |            Open or reversed: 15 V
                              |
   - o------------------------+------------o -
```

The voltage drop in the forward direction should be at least 6 V with a few mA of current but may be somewhat higher (8 V or more) with a few hundred mA. If your DMM or VOM has a resistance scale operated off a battery of at least 6 V, you may get a reading in one direction (but only one) without the need for an external power supply.

Or, assume for now that the diode is good if it is not shorted - which is likely.

Although a shorted HV diode is usually an isolated event, it is possible for failures elsewhere to have caused the diode to blow. Possible causes include a shorted HV cap, arcing between windings in the HV transformer, and possibly even a defective magnetron or damaged waveguide. These may only occur with full voltage so unless there is obvious physical damage (e.g., charring between the HV transformer windings or hole burned in the waveguide), it may be necessary to eliminate the other components one by one.

Replacing the HV diode

WARNING: First, with power disconnected, discharge the high voltage capacitor. See the section Safe discharging of the high voltage capacitor.

Most HV diodes have press fit (Fast-On) or ring lugs so replacement is very straightforward. Discharge the high voltage capacitor. Make sure you get the polarity correct if your replacement can be installed either way. Putting the diode in backwards will result in positive instead of negative high voltage and, needless to say, no heat, but no other symptoms either.

Note: the lugs on your new HV diode may just be crimped onto the wire leads and not welded or soldered. If this is the case, take care not to stress them excessively which might result in bad connections now or in the future. It may be a good idea to solder the lugs to the wires as well (though this may be overkill).

Where the diode is part of the capacitor assembly, it may be possible to just replace the diode leaving the old one unconnected (at one end) as long as the original diode isn't tied to ground inside the case. This will probably be much much cheaper than replacing the entire assembly.

HV diode ratings

Most replacement microwave oven diodes are rated 12 to 15 kV PRV at .5 A. A PRV of around 8 kV is actually required even for a small oven. Here is why: Until the magnetron heats up and starts conducting in its forward direction, what you have is a half wave rectifier/filter formed by the HV transformer secondary, the HV diode, and the HV capacitor. The reverse voltage across the HV diode will be equal to: 2 * 1.414 * (VRMS of the HV transformer). This can easily be 6 or 7 kV or more! Once the magnetron start conducting, the reverse voltage goes down somewhat.

HV diodes rated at .5 A are adequate for most domestic microwave ovens. For example, the largest of these will have a nameplate rating of around 1,800 W power line input and a HV transformer secondary of 2,500 VAC. While there are some losses in the HV transformer, and some power is used by the magnetron filament, controller, motors, and light, this still leaves, perhaps, 1,600 W into the HV generator. However, due to the design of the half wave doubler circuit, not all the power flows through the HV diode (as would be the case with a regular power supply. Thus, even though calculations using Ohms law (I = P/V = 1,600/2,500 or .64 A) would suggest that .5 A is not enough, closer to 1/2 of the total current actually flows through the HV diode.

To be doubly sure that your new HV diode is happy, run the oven on full power (high) for 10 minutes with two quarts of water as a load (or a roast). Unplug the oven (while your spouse prepares the veggies), quickly DISCHARGE THE HV CAPACITOR, and then check the HV diode for overheating. It might be warm but should not be too hot to touch. Unless you have the largest oven on earth, this test is probably not needed.

Testing the high voltage capacitor

WARNING: First, with power disconnected, discharge the high voltage capacitor. See the section Safe discharging of the high voltage capacitor.

- A shorted HV capacitor will blow the fuse instantly.
- An open HV capacitor will result in no heat but no other symptoms.

(The following assumes no internal rectifier or other circuitry except of a bleeder resistor. Adjust procedures accordingly if your oven is different.)

The resistance measured across the terminals of the high voltage capacitor should be very high - several M ohms for bleeder resistor. If it is less than 1 M ohms, the capacitor is definitely shorted. Yes, if you measure 0.00 ohms across the terminals (and they are not bussed together on the case), then the capacitor is positively, without a shadow of a doubt, bad!

A high resistance does not prove that the capacitor is actually functional, just not shorted with no voltage across it. If you have a capacitance meter, check it for proper value (should be printed on the case). Even this does not prove that it will not short when full voltage is applied. Substitution is the only sure test beyond this.

Replacing the high voltage capacitor

WARNING: First, with power disconnected, discharge the high voltage capacitor. See the section Safe discharging of the high voltage capacitor.

Make a diagram of the precise wiring as multiple connections are often made to the capacitor terminals. The capacitor is usually mounted with a clamp which is easily loosened. Sometimes, the capacitor is jammed into a location that requires moving some other components to extract it.

Replace in reverse order. Tighten the clamp securely but not so much as to distort the case.

Where the capacitor assembly also includes the HV diode, it is possible to just replace the capacitor if space permits leaving the old one unconnected (at one end). However, the cost of a generic replacement diode is small (around $3) so replacing both at the same time is usually best. However, you don't need to use the exact combined part - which may be very expensive or difficult to obtain. Just make sure the ratings of the capacitor and diode are correct (use a generic replacement microwave oven HV diode and a microwave HV capacitor with a uF rating within 10% or so of the old one and at least equal working voltage).

What if the HV diode or capacitor are leaky?

An (electrically) leaky HV diode or cap would likely fail totally in short order since it would be dissipating a lot of power. However, until this happened, the oven might continue to operate and not blow a fuse. The effect on performance in both cases would be to reduce the effective voltage across the magnetron and thus the output power.

I consider these sorts of failures somewhat unlikely as the HV diode and capacitor do not generally fail half-way!

Testing the magnetron

WARNING: First, with power disconnected, discharge the high voltage capacitor. See the section Safe discharging of the high voltage capacitor.

- A magnetron with an open filament will result in no heat but no other symptoms. The bad connection may be internal (in which case the magnetron will need to be replaced) or external at the filament terminals (which may be repairable).
- A magnetron with with a short between the filament/cathode and anode will likely result in a loud hum from the HV transformer and/or magnetron when the cook cycle is initiated but the main fuse will probably not blow. However, note that the actual wattage drawn from the power line will probably be *much lower* than under normal conditions. Although there will be a high current flowing in the HV transformer secondary through the HV capacitor (likely causing a loud hum or buzz), the real power consumed will be reduced since the current and voltage will be out of phase (due to the series capacitor) and the power factor will be low. A reading on an AC line wattmeter of 300 W compared to the normal 1,200 to 1,500 W would be reasonable.
- A magnetron with other faults may result in a variety of symptoms including erratic or low output power or intermittent operation. See the section: Comprehensive

list of magnetron failure modes.

There is no totally definitive way to determine if a magnetron is good without actually powering it under operating conditions but the following tests will catch most problems:

- Magnetron filament. The resistance should be infinite from the filament connections to the case and a fraction of an ohm between the filament terminals with the wiring disconnected from the magnetron.

  While measuring resistance from filament chassis, gently tap the magnetron to determine if there is an intermittent short. However, such problems may only show up once the filament heats up and parts expand.

  It may be possible to determine if the magnetron filament is actually working by connecting just the filament connections to a low voltage high current supply on a Variac (e.g., a microwave oven transformer but just the filament connections). Most ceramic insulators are translucent and should show a glow with a working filament. The one at the antenna may be visible if the magnetron is removed from the oven or with a dental mirror looking into the waveguide. WARNING: Make sure you ONLY have the filament connected!

  I tried powering the filaments of a few magnetrons. On those that had white or pink ceramic insulators between the antenna cap and body of the magnetron, the glow was very bright. Even on one with a dark red insulator, the glow could be seen with the lights out.

- Evidence of arcing (visible blackening around ventilation holes in base or burnt odor) usually indicates a bad magnetron.

- Melting or other damage to the antenna cover ('bull-nose' or 'bullet') may be the result of arcing due to problems in the oven cavity or waveguide (perhaps operating with nothing in the oven) or a defective magnetron.

  (This part is only visible with the magnetron removed from the oven). If a problem elsewhere has been corrected, the damaged antenna cover can be pulled off and replaced from a magnetron that died of other causes - try your local appliance repair shop. (The shape doesn't matter as long as it fits tightly - there are several diameters, however.) Your magnetron may still be good.

  Note: Since the antenna is attached directly to one of the vanes which is part of the anode assembly, it will test as a dead short to the case on your multimeter using DC and is normal. At 2.45 GHz, this won't be the case! :)

Most common magnetron failure modes:

- Filament could be shorted to case - check with ohmmeter. Anything less than infinity means the tube is bad though it could be charring due to arcing outside the vacuum in the box with the filament connections. Tap the tube while measuring to check for intermittents.

- Filament could be shorted to itself - tough to test since it is such a low resistance to start. Compare with good magnetron. (Yeh, right. If you had one, this wouldn't be an issue!) Tap the tube while measuring to check for intermittents. This fault isn't really likely.

- Filament could be open - check with ohmmeter. Tap the tube while measuring to check for intermittents. However, loose filament connectors (Fast-Ons) are more likely than a broken filament. Therefore, check directly at the magnetron terminals with both lugs pulled off.

- Magnetron could be gassy (or up to air) and arcover internally once power is applied. The filament could expand, shift position, and short once heated. There is no easy way to test for these possibilities other than substituting a known good magnetron.

- Internal or external arcing resulting in physical damage. External arcing could be at the antenna or inside the filament box. Internal arcing will not leave any visible evidence but the damage will result in the magnetron failing totally or running with reduced output.

- Overheating might result from a broken or cracked magnet (reduced magentic field) or other internal problems. While there may be some output power, the thermal protector will shut down the oven prematurely.

Comprehensive list of magnetron failure modes

(Portions from: John Gallawa (john@microtechfactoryservice.com).)

Here is a list of typical magnetron failure modes. The percentage of each type of failure varies. Currently, internal shorts and loose filament connectors are probably at the top of the list. An internal plate-cathode short may only manifest itself under the stress of high voltage during operation.

1. Shorts. (a) Internal plate-cathode/filament short or (b) Internal arcing.

   Symptoms: No heat, loud hum when entering cook cycle, possible blown HV fuse (but will not likely blow the main fuse).

   In ovens equipped with fuses that monitor the high voltage system, such as some commercial Sharp models and most commercial and domestic Amana models, the high voltage fuse would probably blow. But, rarely will a shorted magnetron cause the main line fuse to blow. (I suppose the transformer absorbs most of the current surge.) In fact, with reference to the other symptoms below, there are almost no failures where the magnetron causes the line fuse to blow.

2. Loose filament connectors (these may be repairable). There will often also be visual symptoms at the magnetron: Signs of overheating, such as discoloration; and evidence of carbon tracks or pits on magnetron terminals when the connectors are removed. An intermittent filament (internal) is also possible (but not repairable).

   Symptoms: No heat or erratic heat.

   The slip-on connectors can loosen, overheat, build up resistance and eventually loose contact. If the the magnetron terminal(s) have not been burned too severely, the connection(s) can usually be repaired. We prefer cleaning up the terminal, then soldering the filament wires directly to the terminal.

   Note: when discharging HV capacitor, since there is no load, it may end up being charged to a much higher voltage than is normal. Be prepared for a larger spark if you use a screwdriver to discharge it!

3. Open filament.

   Symptoms: No heat.

   See note about HV capacitor in (2) above.

4. In the older glass-dome models, the vacuum envelope can rupture.

   Symptoms: No heat, loud buzz due to arcing when entering cook cycle, possible blown HV fuse.

   See comments about fuses in (1) above.

5. Filament breakdown. Usually occurs after a few minutes of normal operation, possible blown HV fuse.

   Symptoms: No heat, loud hum once it occurs.

   See comments about fuses in (1) above.

6. Low output. Occurs as cathode emission decreases from long use.

   Symptoms: Reduced cooking power.

7. Moding. Occurs when magnetron oscillates in one or more undesirable frequencies.

   Symptoms: (a) Reduced or no cooking power, (b) RF interference. However, some food products (with high water content) may cook normally, whereas the result with other foods is very unsatisfactory. RF interference is possible but usually only occurs if there is actual structural damage to either the magnetron, its RF gasket or waveguide flange, or its RF (feed-through) capacitors.

8. Off frequency. Physical characteristics can change and cause magnetron to oscillate at frequencies slightly higher or lower than 2.45 GHz.

   Same as (7a) above.

9. RF leakage. Structural failure can cause leakage from magnetron housing.

   Symptoms: Microwave leakage into electronics bay, erratic control panel behavior. It can be very frustrating because the symptoms disappear when the oven's outer cover is removed. With the cover in place, the escaping RF energy is confined, and eventually builds up around the control panel circuitry causing unusual symptoms.

10. Insulation breakdown of the internal leads or at magnetron insulators or antenna terminal.

    Symptoms: Arcing, burning smell from magnetron, loud hum, no heat.

11. Cracked magnet(s).

    Symptoms: Reduced or no cooking power, magnetron overheating, occasional 'snapping' sound.

Where to obtain replacement magnetrons

Depending on the age of your oven the magnetron may still be under warranty. Check the original paperwork that came with the oven - either the users manual or a separate warranty document. Contact the manufacturer if specific instructions on how to file claims are not provided. Full coverage on the magnetron of several years is common. If you have not sent in the warranty registration card (right, who actually does this?!), a copy of the sales receipt or other proof of date of purchase may be required.

Both original and generic replacement magnetrons are available. Going direct to the oven manufacturer will guarantee a compatible magnetron but is by far the most expensive option. For a typical oven, one without the gold-plated trim :-), such a replacement may be more than half the cost of a similar new oven. In some cases (like Sears), you may need to convince their service department that you are qualified to be poking around inside one of *their* appliances before they will consider selling one to you (too many lawyers).

In some cases, original magnetrons may also be available from parts suppliers like MCM Electronics - at somewhat less rediculous prices. They will be identified as 'original' or 'genuine' along with the manufacturer and their part number.

Generic replacement magnetrons are available for the majority of microwave ovens. These will almost certainly be much less expensive than original parts. Essentially, there is only one type 'tube' (at least for any similar power range). The differences are mostly mechanical - which side the filament connections are on, the location of screw holes and whether they are tapped, and so forth. Sometimes, it's possible to make the wrong style fit but this should be avoided, especially if it requires forcible changes to the magnetron structure. However, quality may vary. In some cases, the generic variety may actually be better than the original. See the section: Comments on replacement magnetron quality for some recommendations.

However, it turns out that eBay can be an excellent source of genuine "new" magnetrons. These may be removed from cosmeticly damaged or otherwise un-saleable ovens. It is often possible to find the exact original make and model with a simple search. The cost is likely to be as low or lower than for a generic replacement from a repair parts distributor. Of course, as with anything else on eBay, checkout the reputation of the seller via the Feedback rating and associated comments.

Comments on replacement magnetron quality

(From John Gallawa (john@microtechfactoryservice.com).)

In my experience, mags purchased from after-market suppliers may or may not be OEM parts (there are not that many manufacturers of magnetrons in the world).

Here's the interesting thing, though: In many cases, these after-market tubes are actually higher in quality than the original tube, as in the case of the OEM Sanyo magnetrons, which tend to fail prematurely. Of course, the opposite can also be true, depending on the after-market supplier. Some manufacturers, such as Toshiba and Hitachi, produce both high and low end magnetrons. They sell these under a variety of specialty names, as well as under manufacturer brand names. I have seen the low-end tubes in many brand-new microwave ovens.

When buying magnetrons from other than the manufacturer, I have found it best to go to a supplier who specializes in microwave oven parts (i.e. AMI, Global Micro-parts, QB products). These sales people are usually more knowledgeable about the magnetrons they sell, and they can help you with proper choice and application.

Replacing the magnetron

WARNING: First, with power disconnected, discharge the high voltage capacitor. See the section Safe discharging of the high voltage capacitor.

When you receive the replacement, compare it with the original. It is critical that the replacement magnetron be mechanically identical: this means that the mounting configuration (studs or holes and their location), waveguide seating surface, and the orientation of the filament connections and cooling fins are the same. The studs may be removable so that the same assembly can be used with or without them. The cooling fins are particularly important as there must be adequate airflow from the fan for removal of the substantial waste heat - up to half of the input power to the magnetron ends up as heat. The shape of the antenna terminal - cone, bull nose, or square - doesn't matter.

Magnetron replacement is generally straightforward but other assemblies like the cooling fan may need to be removed to gain access. Make careful notes of both the wiring and mechanical relationships. Usually, the magnetron is fastened to the waveguide with 4 nuts on studs. When removing it from its mounting, do not lose the RF gasket - a metal mesh ring which seals the connection against microwave leakage. Reuse it unless your replacement magnetron comes with a new one. Transfer any thermal protector to the new unit. Replace other components in reverse order and then reattach the filament and HV wires.

Although the magnetron is a vacuum tube, there is probably no glass in yours (unless it is quite old) so it isn't really very fragile. However, a sharp blow or fall (during shipping as well if not properly packed) could shatter the filament. Do keep it (the magnets) away from your diskettes unless you want them bulk erased!

As for the old one, see the section: The magnets in dead magnetrons. :-)

Testing the high voltage transformer

WARNING: First, with power disconnected, discharge the high voltage capacitor. See the section Safe discharging of the high voltage capacitor.

- A shorted winding or short between a winding and the core/chassis in the HV transformer may result in a blown fuse, loud hum, overheating, audible arcing, a burnt aroma, or simply no heat.
- An open winding will likely result in no heat but no other symptoms.

The typical schematic is shown below:

```
                            +-------------------o White wire
                         ||( Filament winding
                         ||  +-------------------o White wire
                         ||
                         ||  +-------------------o Red Wire
 AC H o---------+ ||(
                        )||(
                        )||( HV Winding
         .1 to .5 )||( 1.5 to 2.5 KV RMS
              ohms )||( .5 A or MORE
                        )||( 25 to 150 ohms
                        )||(
 AC N o---------+ ||(
                          | +-+ HV return connected to frame
                          |    |
 AC G o------------+---+
```

Disconnect terminals as required to make the following tests:

- The resistances of the primary should be .1 to .5 ohms (.2 ohms typical).
- The resistance of the filament winding will likely be so low as not to be detectable with your multimeter. The only measurement easily made would be that there is no short to the chassis.
- Typical resistance readings for the transformer HV secondary are in the 25 to 150 ohms range (depending on the power rating of the oven) from HV connection to chassis. A typical midsize might be 65 ohms. An open would be an obvious failure. However, based on the way these are wound, a winding-to-winding short would not cause enough of a resistance change to be detected with an ohmmeter unless you could compare with an identical model transformer from the same lot number.
- Check the resistance between all windings (and to the core):
  - Filament to primary, high voltage, and core, should be infinite.

    It may be possible to repair a filament winding which is shorted to the core (the only likely place) as it is only 2 or 3 turns of heavy wire. However, it must be insulated for 5,000 V, may get quite hot with normal use, and similar fire resistant materials must be used for the repair as were present original. However, if the filament winding is adjacent to the HV winding (in the same channel), the arcing may have been taking place to the HV winding rather than the core. Therefore, you need to make sure that it hasn't been damaged as well.

    - Primary to high voltage and core should be infinite.
    - High voltage to core should be between 25 and 150 ohms as discussed above.

- If you have a clamp-on ammeter, you can measure the primary current with all secondaries disconnected. See the section: Testing the HV transformer using an AC current meter.

Testing the high voltage transformer more fully is difficult without fancy equipment. Only major short circuits can be identified in the transformer with an ohmmeter since the nominal resistance of the windings is unknown. However, open windings (not very likely) can be located and other faults can be identified by the process of elimination.

Note: in the discussion below, it is assumed that the fuse is blowing due to a possible short in the HV transformer. Alternatively, there may be a loud hum as the HV transformer struggles due to a fault in the HV transformer or a shorted HV diode, magnetron, or a short in the HV wiring. Also note that depending on the severity of the fault, the fuse may not actually blow (at least not immediately) but there will likely be a loud hum when the HV transformer is powered.

- Disconnect the primary of the HV transformer and initiate a cook cycle. If the fuse still blows, you have a problem elsewhere such as a defective interlock or shorted wire.
- Assuming the fuse does not blow, unplug the oven and reconnect the primary of the HV transformer.
- If the other components - HV diode, HV capacitor, magnetron - test out, remove the high voltage and filament connections to the transformer, power up the oven, and initiate a cook cycle. If the fuse does not blow, the transformer is likely good and there are still problems in the high voltage components. Possibly something is failing only when full voltage is applied.
- If the fuse still blows, then the problem is likely with the triac (if used), a shorted wire, or shorted transformer.
- If the fuse does not blow with the secondary isolated, reconnect only the magnetron filament (not the HV) to the transformer and power it up again. If the fuse now blows, then it is possible that the magnetron filament is shorted.
- If your oven uses a triac, remove and bypass it. Now, if the fuse still blows when the oven is plugged in (door closed to enable the interlocks), the problem is likely with the transformer.

  Unplug the oven, discharge the HV capacitor.

- Check for damaged wires that may be shorting to the chassis. Repair or replace these as necessary.

Testing the HV transformer using an AC current meter

Where the HV transformer doesn't blow a fuse but overheats or produces insufficient output, this test may be useful. If you have a clamp-on AC ammeter, the transformer can be powered up to see if the primary current it draws is reasonable with no load.

WARNING: Up to 3,000 VAC on HV terminal - AND possibly other windings if there is a short in the transformer somewhere. Use a 3 prong cord with H and N connected to the primary and G firmly screwed to the transformer core/mounting structure. Or, just remove the 3 secondary connections and power it through the existing wiring using the normal oven controls. The meter's clamp needs to go around H or N but not both. Stand well clear when you apply power!

Use of a Variac is recommended but not essential. However, here are the input current readings at various input voltages for the HV transformer from a typical mid-size microwave oven:

Input VAC	Input Amps
80	.3
90	.6
100	1.1
110	2.0
115	3.0
120	>4.0

Above about 100 VAC, there was also a noticeable hum (though not nearly as great as with a secondary short).

No, these readings do not indicate a problem. Microwave oven transformers are designed with as little copper as possible. And, yes, the non-linear increase in current indicates that the core is saturating with no load.

If your readings are similar to these, the transformer is likely good. Shorted turns would result in much higher current at all input voltages.

Replacing the high voltage transformer

WARNING: First, with power disconnected, discharge the high voltage capacitor. See the section Safe discharging of the high voltage capacitor.

Replacement of a HV transformer is straightforward but other assemblies may be using the transformer bolts for their mounting and/or may block your way.

Label the wires before pulling off the Fast-Ons if there is any doubt as to where they go.

If the replacement transformer is not mechanically identical, you may need to use some creativity in anchoring it and any structures that are attached to its frame. However, the transformer must be secure - don't just sit it in place.

Try not to drop either the old or new transformer on your foot!

Testing and repairing the wiring and connections

WARNING: First, with power disconnected, discharge the high voltage capacitor. See the section Safe discharging of the high voltage capacitor.

Inspect the wiring - especially between the magnetron, HV transformer, and other components of the high voltage circuits for signs of arcing and excessive heating or burning. Arcing may be the result of the wire scraping against a sharp sheet metal edge due to poor placement and or vibration. A bit of electrical tape may be all that is needed.

Since the magnetron filament in particular uses high current, any resistance at the press (Fast-On) connections will result in heating, weakening of the lug, more heating, and eventual failure or erratic operation. Try to pull off each of the lugs. They should not be loose - you should have to work at removing them. However, note that some lugs are of the locking variety and require that you push a little tab to release them.

Check for loose, burnt, or deteriorated lugs in the filament circuit (not just the magnetron). If you find evidence of this:

- Remove the lugs and clean the terminals with fine sandpaper or a file. If they are not too badly deteriorated, they will still work even if they are somewhat ugly.
- If the lugs and their wire connections appear to be in good condition but come off their terminals easily, try squeezing them a little tighter with a pair of pliers and reinstall. Otherwise, cut off the old ones and replace them.
- If any connections between the lug and the wire or HV diode are at all loose, solder it with a high wattage soldering iron or soldering gun.
- Alternatively, use a drill to make a hole in each terminal, and then fasten the (tinned) wire directly (or better yet) a new ring lug to the terminal with a machine screw, nut, and lockwasher. Soldering is also possible.

  These approaches will work as long as there is enough metal remaining for a solid connection and may permit you to salvage a magnetron or HV transformer that would otherwise need to be replaced.

Also check for bad solder connections between the terminals on the high voltage transformer and the enameled wire used for its windings. If you find anything suspect, scrape away the enamel and surface corrosion and resolder with a high wattage soldering iron or soldering gun.

Testing thermal protectors and thermal fuses

There may be two types of devices present in your oven:

- Thermal protectors are thermostats that open a set of high current contacts at a preset temperature. They should reset when they cool off. However, like a relay or switch, the contacts sometimes deteriorate.
- Thermal fuses will open at a preset temperature but do not reset. They blow and need to be replaced.

At room temperature, both types should read as a dead short with an ohmmeter (disconnect one terminal as there may be low resistance components or wiring which may confuse your readings). If the resistance is more than a small fraction of an ohm, the device is bad. Replacements are somewhat readily available. You must match both the temperature and current ratings.

If you suspect a bad thermal protector in the HV transformer primary, clip a 100 W light bulb or AC voltmeter across it and operate the oven. If the thermal protector is functioning properly, there should never be any voltage across it unless there is actual overheating. If the bulb lights up or the meter indicates approximately line voltage - and there is no sign of overheating - the thermal protector is defective and will need to be replaced.

An overheating condition would generally be obvious as the mounting surface on which the thermal protector is located would be scorching hot when it tripped - too hot to touch (but discharge the HV capacitor first - a burn from the heat will be nothing compared to the potential shock!).

Replacement of a thermal protector is very straightforward as it is almost always screwed in place with push-on lug terminals. The new thermal fuse will probably come with lugs attached.

Testing and replacing the triac

A triac may fail in a variety of ways:

- A shorted triac would result in the oven coming on as soon as the door is closed or the power being stuck on high no matter what the touchpad setting.
- An open triac or one that didn't respond to the gate would result in no heat and possibly other things like the fan and turntable not working as well.
- A triac that didn't turn off would result in the parts of the oven continuing to run even after the timer counted to zero.
- A triac where one half was shorted would result in a blown fuse due to it acting as a rectifier pumping DC through the HV transformer.
- A triac where one half doesn't properly turn off would result in the main fuse blowing when the cook cycle completed.

Nearly all triac failures will be shorts. Thus, measuring across the MT1 and MT2 terminals of the triac (the power connections) should read as a high resistance with a multimeter. A few ohms means a bad triac.

As noted above, triacs can fail in other - possibly peculiar ways - so substitution or bypassing may be necessary to rule out all possibilities.

Replacement is very straightforward - just don't get the wires mixed up.

Testing and replacing the power relay

A defective relay can result in a variety of symptoms:

- A relay with its contacts welded (stuck) closed would result in the oven coming on as soon as the door is closed or the power being stuck on high no matter what the touchpad setting.
- A relay that doesn't close (due to defective contacts or a bad coil) would result in no heat and possibly other things like the fan and turntable not working as well.

If the relay is totally inoperative, test for voltage to the coil. If the voltage is correct, the relay may have an open coil. If the voltage is low or zero, the coil may be shorted or the driving circuit may be defective. If the relay makes a normal switching sound but does not correctly control its output connections, the contacts may be corroded, dirty, worn, welded closed, binding, or there may be other mechanical problems.

Remove the relay from the circuit (if possible) and measure the coil resistance. Compare your reading with the marked or specified value and/or compare with a known working relay of the same type. An open coil is obviously defective but sometimes the break is right at the terminal connections and can be repaired easily. If you can gain access by removing the cover, a visual examination will confirm this. If the resistance is too low, some of the windings are probably shorted. This will result in overheating as well as no or erratic operation. Replacement will be required.

The resistance of closed contacts on a relay that is in good condition should be very low - probably below the measurable limits on a typical multimeter - a few milliohms. If you measure significant or erratic resistance for the closed contacts as the relay is switched or if very gentle tapping results in erratic resistance changes, the contacts are probably dirty, corroded, or worn. If you can get at the contacts, the use of contact cleaner first and a piece of paper pulled back and forth through the closed contacts may help. Superfine sandpaper may be used as a last resort but this is only a short term fix. The relay will most likely need to be replaced if as in this case the contacts are switching any substantial power.

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Items of Interest

Not your typical home microwave oven

(From: Daniel Armstrong.)

I own an Amana Commercial Radarange RC22LW. The specs are: 4 kW input power, 2.2 kW output power, 3 magnetrons each on its own HV transformer, etc., and a roughly $3,000 price tag.

The oven cavity is 15" deep x 13" wide x 9" tall. Most of the comments I hear about it are from people who are scared of the fact that the light, blower, etc. all turn on as soon as the door is opened/closed or the stop button is pressed and shuts off about 30 seconds after the door is left open or shut without pressing any buttons. They are used to consumer level models where the fan and light are only on while cooking.

It operates on a standard 230 VAC 20 A circuit and everything inside including the cavity light bulb are 230 V as there is no neutral conductor in the cord. It has 2 magnetrons firing down from the top of the cavity and 1 firing up from under the ceramic floor. It is wired so that the top 2 fire on the positive alternation of the AC cycle and the bottom 1 on negative. It has auto-sensing for incoming line voltage and frequency including 208 and 230 VAC terminals on the HV transformers and a small buck/boost transformer to boost the voltage to the antenna motors, cooling blower, and cavity light to 230 when connected to a 208 supply. The timer compensates for the filament preheat time using a current transformer on one of the main supply wires to sense when the magnetrons are actually producing output power (i.e., it waits ~2 seconds before starting to count down and 50% power is ~7 seconds on 5 seconds off). It has 2 thermal cutouts on each magnetron, 1 high voltage in the primary for that transformer, and 1 low voltage that causes the cook cycle to stop and the display to read "HOT" when unplugged/tripped. The 3 low voltage cutouts are simply wired in series. There is also a thermal fuse in the air exhaust duct and a 30 amp line fuse.

How I acquired it is that my mom worked at a Hardees (Carl's Jr. in the western USA) restaurant and they gave me 2 of them because they had died. I discovered that one had the magnetron antennas burned from underloading and the other had the door interlock switch contacts welded from opening the door while operating, so I combined them into a working unit.

I used the information here for testing output power via the temperature rise of water and came up with a value of 1.9 kW so I will be investigating that next but otherwise it works great and I love stainless steel appliances. I still love to impress people by popping a bag of popcorn in 72 to 75 seconds.

You can find complete diagrams and parts lists at: Maytag Services On-Line Parts Store. Just enter the the RC22LW model number and then click the radio button for the P1198611M manufacturing number.

Microwave leakage meters

A routine test for radiation leakage should be done before returning an oven you have worked on especially if the door or magnetron/waveguide were disturbed during the repair process. Use it around the door seem and ventilation holes in the cabinet. An inexpensive meter is better than nothing but will not be as sensitive and will not allow you to quantify the amount of any leakage.

If you work on microwave ovens, such a meter is a *must* for personal safety reasons as well as minimizing the risk of liability after returning them to your customers.

These should be available wherever you buy quality test instruments. They are usually made by the same companies that manufacture other service equipment. Prices and capabilities vary widely. MCM Electronics sells an inexpensive unit suitable for quick checks on a go/no-go basis for $6.99 and an FDA approved unit (including calibration), for $388.

Note: you should also perform an electrical leakage test to assure that all case parts are securely connected to the Ground of the AC plug.

Comments on microwave leakage meters

(From Barry Collins (bcollins@mindspring.com).)

I found an old manual for a Narda 8100B Electromagnetic Leakage Monitor. (I used to work for a manufacturer of Microwave ovens.) While I don't personally recall ever having damaged a probe while checking for leakage, I do know that it is possible to do so and did happen on rare occasions.

The Narda manual states that their probes use an antenna/thermocouples design. Holaday (sp?) makes another line of detectors and those may use a thermistor array.

I have confirmed that by removing the styrofoam cone from the end of a Holaday uW leakage detector's probe and then bringing its tip near a heat source (40W bulb) caused the meter to have a significant deflection. Thus, the cones are not only used as spacers. They prevent radiant heat sources from affecting the meter reading, as well.

The Holaday probes that I used had 8 diodes in the tip that formed an array.

Newer designs (Holaday) claim to be more or less immune to damage resulting from placing them into high energy fields. I do know that the older Narda equipment was prone to such damage.

There is a section in the Narda manual that details how to select the proper probe to measure "unknown" leakage levels. In a nutshell, one should start with the highest power rated probe and work toward the lowest power rated probe (three listed in all). The goal is to have a meter deflection of more than 10% of it's scale while not going off scale for sake of accuracy. While it didn't specifically mention damage to the probes, there were overtones throughout the text that implied such (watch needle, listen for alarm, stop and replace probe, etc...).

The three probes were listed as (high/low range for each):

Probe	Range
8120A	0.2 mW to 2.0 mW/square cm
8121A	2.0 mW to 20.0 mW/square cm
8122A	20.0 mW to 200.0 mW/square cm

This is from memory, but I believe that the maximum leakages we were allowed by the governmental agency were:

- Less than 2.0 mw/square cm off of our assembly line
- Less than 3.0 mw/square cm leaving the warehouse
- Less than 5.0 mw/square cm in consumers home

As you no doubt know, with a hole cut in the oven (in reference to those who want to modify one - see the section: Microwave ovens for non-standard applications --- sam), the density can easily reach several times these numbers, especially on the newer 1,000 watt plus models. Damage would occur where one intentionally held the lower power rated probe in the strong field until the thermocouple (or thermistor?) overheated.

Simple microwave leak detectors

Since these do not really provide an absolute measurement, their utility is somewhat limited. All microwave ovens leak to some extent. Determining by how much is why you pay the big bucks for a real leakage meter!

WARNING: These are no substitute for a properly calibrated commercial unit!

(From: Leon Heller (leon@lfheller.demon.co.uk).)

A very simple design I saw somewhere (Electronics World, probably) consisted of a half-wave dipole with a Shottky diode detector between the two elements. I think one measured the voltage across the diode via a resistor and capacitor smoothing arrangement using a 50 uA meter. You can buy these detectors quite cheaply.

(From: Ren Tescher (ren@rap.ucar.edu).)

I saw an article about it in Modern Electronics in the early eighties. It is simply a Schottky Barrier Diode (SBD) and an LED wired together. The leads of the SBD are left intact and straight and act as a 1/4 wavelength dipole.

Here's the circuit:

```
                    SBD
<------------------+-|<|-+------------------>
                   |     |
                   +-|>|-+
                    LED
```

The LED is soldered close to SBD using as short of leads as possible (being careful not to ruin either part with too much heat). (Note that the diodes are connected anode to cathode, not cathode to cathode.)

I then taped/glued it 1 1/2 and perpendicular from the end of a popsicle stick (this gives it a 'standoff' distance).

Put a large container of water (>=2 cups) in the microwave and run it on HIGH for 2 minutes. While it is running, slowly sweep the tester around the door seal, hinges and door latch. You may have to dim the lights to see if the LED lights up.

Any leaking uwaves will be picked up by the dipole 'antenna', the SBD will rectify the waves, and when sufficient rectified voltage has built up, the LED will light up.

I built 10 of these at home and then compared them to the commercial tester we had at work. The commercial tester had three ranges and the most sensitive range was divided into 3 color bands, red, yellow, green. The home-built testers all 'fired' at some point in the 'yellow' range. I attribute the variances within the yellow (caution) range to individual characteristics of the diodes - they all came from the bargain bin at Radio shacks....

A solid glow would indicate excessive leakage, especially if the tester still glows if it is pulled beyond the 1-1/2 inch standoff distance to 3 inches. Typically the LED just flickers, around the hinge/latch areas. (US law allows increased leakage as the oven ages).

You may notice that no radiation leaks through the viewing window, contrary to the old wives tale of not looking through the window while it's cooking. (The screen really is a very good microwave shield --- sam).

Small leaks may be remedied by adjusting or cleaning the door and hinges and/or by distance (square law= doubling the distance quarters the power). Large leaks - trash the oven.

(From: James P. Meyer (jimbob@acpub.duke.edu).)

Get a small neon bulb. The NE-2 size is a good one. Use some resistors to make a voltage divider for 115 VAC to feed the bulb. Adjust the voltage across the bulb so that it's just barely glowing. Make the divider network resistance large enough to limit the current through the bulb to just a couple of mA. Put the bulb on the end of a line cord and plug. INSULATE everything completely.

Adding this onto a neon circuit tester is one option and will provide an insulated housing as well.

Plug the whole thing into an AC outlet. Wave the bulb around the door gaskets and if it gets brighter when the oven is turned on, then you have located a leak. The bulb detector can be very sensitive. You may even be able to use it to find wires behind drywall in your house.

How safe is a repaired microwave oven?

So you fixed up Aunt Minnie's Radarange or picked up a microwave at a yard sale or scavenged one off the curb. The only problem you could find was a blown fuse, truly horrible mess of decayed burnt-on food, or a thriving community of cockroaches inside. How safe is it to use (assuming you evicted the cockroaches)?

As long as there is no serious damage to the door (a 6 inch hole would quality as serious damage) and the door fits square, it should be properly sealed. As long as the waveguide is tightly mounted and undamaged, there should be no leakage from there. Make sure the metal cover has all its fingers engaged around the front (though with a properly installed magnetron, there should be minimal microwave leakage into the electronics bay).

An inexpensive leakage tester - around $8 - will not be as sensitive or accurate as the $500 variety by may provide some peace of mind. However, as noted below, they may indicate dangerous leakage even when your oven is within acceptable limits.

The most important considerations are the door and door seal.

(From Barry Collins (bcollins@mindspring.com).)

Those inexpensive hand held meters (from Radio Shack, etc..) can give very inaccurate readings. While they definitely serve a purpose, they have caused a more than a few people to unnecessarily fear microwave ovens over the years. Also, I just changed jobs from working for a company that made gas ranges. CO detectors caused similar panic among users of the appliances. I'd highly recommend anyone with gas heat or appliances to purchase a quality CO detector, but not one of those inexpensive type that go off whenever there is a thermal inversion of smog a city.

Efficiency of microwave ovens

The efficiency of an electric heating element is 100% - period. However, using an electric stove to heat 1 cup of tea may result in much wasted energy as the element and pot must be heated as well and there are losses due to convection and conduction to the surrounding environment. Furthermore, you won't heat just *1 cup* of tea but more likely 2 or 3 just to be sure you have enough!

A microwave oven is not likely to be more than 60% efficient - possibly as low as 50 percent or even less. While the magnetron tube itself may have an efficiency rating of 75%, there are losses in the high voltage transformer, cooling fans, and turntable motor (if used). The light bulb and controller also use small amounts of power. These all add up to a significant overhead. In addition, the waveform applied to the magnetron by the half wave doubler circuit is not ideal for maximum efficiency.

However, you are not heating the surrounding countryside as the microwaves only affects what you are cooking and not the container or oven cavity itself and you are more likely to only load the amount of food you expect to be eating. For a single cup of tea, the microwave oven may use 1/10th the energy of a typical electric cooktop element to bring it to a boil!

Therefore, it makes sense to use a microwave oven for small short tasks where the losses of an electric or gas oven or cooktop would dominate. However, gastronomic preferences aside, a conventional oven is better suited for that 20 pound turkey - even if you could distort its anatomy enough to fit the typical mid-size microwave!

Microwave oven design and cost reduction

(From Barry Collins (bcollins@mindspring.com).)

Microwave oven design is a black art. What one hopes for is to deliver all the power from the magnetron into the food and not have a high SWR reflect back into the magnetron and burn it out. Size, shape, placement of food items affect the SWR. The microwaves are designed for the most part to work optimally with an average load. Models equipped with turn-table models compensate for this by breaking up the SWR as the food revolves. My oven has a stirrer fan design and has been working for going on 18 years now without the first hint of a problem (maybe a little less power). I personally know that it had one of the lowest SWRs available at the time. Not to mention it has an older design, non-cost reduced, cooler running, more efficient magnetron (that cost $13.00 instead of $9.45). The thing that I found disturbing about microwave oven design was the trends to go with hotter an hotter insulation classes on the components used in them. The original transformers were class H while the newer ones are now class N. This was all done in the name of cost reduction to remain competitive. The windings AWG got smaller and the temperature rise went up accordingly. The magnetrons were cost reduced in a similar fashion. Size was reduced and the number of fins were reduced. Their temperature went up while their efficiency went down. But then the cost went from $300 to $149 while life went from 10 years-plus to 5 years or less and they became disposable items. That's one area, I'd almost hesitate to hope the Government would have mandated an efficiency.

Problems with running a microwave oven with metal inside or totally empty

Metal in microwave ovens may or may not be a problem depending on the specific situation. Sharp edges and points create strong field gradients which tend to spark, arc, or create other fireworks. With some food in the oven to absorb the power, this is probably not likely to damage the oven. You will note that some ovens come with metal fixtures in addition to the oven walls themselves (e.g., Sharp convection/microwave combo).

Having absolutely nothing in the oven chamber or just metal is the potentially more likely damaging situation for the magnetron as you are dumping several hundred W to over a kW of power into a reflective cavity with no load. In the worst case, you could end up with a meltdown inside the waveguide requiring replacement of various expensive components including the magnetron.

Older microwave ovens with used glass magnetrons were perhaps more susceptible to these disasters (all modern overs use magnetrons with ceramic construction but I really don't know how much this matters) but it's still a good idea to avoid running a microwave empty. They don't need preheating! :)

More on metal in the microwave

(From: Don Klipstein (don@Misty.com).)

Mainly, you need exposed water or food to absorb the microwaves. Otherwise, they just reflect around the oven and get back to the magnetron tube. This may be bad for the tube, and in an unpredictable manner.

It is even not too good to run a microwave empty. The walls of the main cooking chamber are metal.

In the event the microwave runs empty OK, adding metal objects change the microwave reflection pattern and might possibly unfavorably change things.

If you have exposed food or water, the tube should not mind some stray metal too much. If the added metal does not interfere with microwaves mainly getting from the tube to the target food or water and being absorbed, the magnetron should be OK.

Even if the tube does not mind, there is another concern. Metal objects close to other metal objects or to the walls of the cooking chamber may arc to these. Any arcing is generally not a good thing. If you add metal objects in a manner safe for the tube, try to keep these at lease a half inch (a bit over a cm.) from the walls to avoid arcing. Safe distances are uncertain and are usually less if the metal objects are small and a large amount of food or water is exposed.

If any metal object has major contact with a microwave absorbing food target and such target is still heavily exposed, you should be OK. Examples would be wrapping foil around the wingtips of a whole chicken or whole turkey, or a bottle of liquid (on its side) with a metal lid with liquid contacting much of the lid. This is usually OK. Just avoid unrelated problems due to major temperature change of anything in contact with a non-heat-rated glass container.

A plain glass bottle if ice-cold stuff might possibly break from thermal shock when heated, but any metal lid on a bottle largely full of microwave-absorbing stuff should not present a problem especially if the bottle is on its side so that stuff is contacting or very nearly contacting much of the lid.

Burnt smell from oven - after incident

> "My daughter tried to heat up one of those 'soup in a box' containers and it burned - actually charred. I wasn't home at the time, so I don't know if it was neglect or inappropriate use, but the lasting effect is that there is a strong odor, similar to that which you smell after a fire that I cannot seem to get rid of. What do you recommend. I have a Sharp Convection/Microwave, that even after the incident described still performs well."

Start by cleaning the interior of the oven thoroughly with mild detergent and water. You may have to do this several times to get all of the sticky film left behind. If this doesn't help enough, smoke may have gotten into the waveguide above the oven chamber. If possible, remove the waveguide cover and clean it and as best as possible the accessible part of the waveguide.

However, the odor may persist since the smoke can penetrate to places you cannot access for cleaning. With a combination convection and microwave oven especially, there are many passages where the air would normally circulate in convection mode which will be coated even if the oven was used in microwave mode. However, I would expect that the smell will decrease and eventually go away. Most likely, nothing in the oven has actually sustained any damage.

Some have suggested boiling a cup of lemon scented water or vinegar to help speed things along. It won't hurt - maybe even help. :) Also, putting a container of used coffee grounds in the oven overnight for several nights should help clear the odor.

Microwave ovens and grounded dedicated circuits

A microwave oven should be used only on a properly wired 3 wire grounded circuit. Check with a circuit tester to make sure your 3 prong outlet is correctly wired. Many are not. Install one if it is not grounded. There is a very important safety reason for this requirement: the return for the high voltage is through the chassis. While unlikely, it is theoretically possible for the entire high voltage to appear on the metal case should certain internal connections come loose. With a properly grounded outlet, this will at most blow a fuse. However, with the case floating, a shocking (or worse) situation could develop - especially considering that microwave ovens are usually situated near grounded appliances like ranges and normal ovens and wet areas like kitchen sinks.

A dedicated circuit is desirable since microwave ovens are significant users of power. Only about 50 to 60% of the electricity used by a microwave oven actually gets turned into microwaves. The rest is wasted as heat. Therefore, a 700 W oven will actually use up to 1400 W of power - nearly an entire 15 Amp circuit. Convection ovens have heating elements which are similar energy hogs. At least, do not put your refrigerator on the same circuit!

Microwave ovens and GFCIs

A Ground Fault Circuit Interrupter (GFCI) protects people from shocks should a situation develop where an accessible part of an appliance should short to a live wire. Touching this may result in a shock or worse. A GFCI detects any difference between the currents in the Hot and Neutral wires and shuts off the power should this difference exceed a few mA.

A GFCI is not needed with a properly grounded microwave oven as any such fault will blow a fuse or trip a circuit breaker. In most cases, it will not hurt to have a GFCI as well. However, with some combinations of oven design and your particular wiring, due to the highly inductive nature of the high voltage transformer, nuisance tripping of the GFCI may occur when you attempt to cook anything - or at random times. However, this usually does not indicate any problem. Plug the oven into a properly grounded circuit not on a GFCI.

Can a microwave oven be built into (or hung under) a cabinet?

Assuming it is a regular microwave and not a convection/microwave combo, the major issues are:

- Providing adequate air flow through its ventilation grill which is usually located in the rear.

  (A convection/microwave can get quite hot and have ventilation in other places. In this case I would suggest contacting the manufacturer of the oven for specific requirements.)

- Providing adequate structural support so the microwave doesn't end up in the soup. :-(These are HEAVY appliances - cabinetry and/or drywall may not be up to the task. Models designed as over-the-range or combined microwave and exhaust fan units mount via a massive plate fastened securely into the wall structure (screwed directly to the studs, not just the sheetrock!). They may additionally be bolted into the cabinet above but this will not (or should not) be the sole means of support.

- Local building codes may specify when and if this approach can be used. So, before doing any demolition, check with your friendly township inspector!

There are special (likely highly overpriced) models available for this type of mounting.

To use a normal microwave, my recommendation would be to build a shelf rather than a totally sealed, enclosed, conformal cabinet. It can have sides and a top as long as you leave a couple of inches all around. This will result in a microwave oven that is much more easily serviced should the need arise and replaced in the future with a model that is not quite identical.

Just make sure it is securely supported - the microwave weighs quite a bit and must endure a fair amount of abuse from heavy casseroles and the inevitable door yanking/slamming!

Note that one of the advantages of buying a microwave oven designed for under cabinet or wall mounting is that it may provide convenient access for servicing from the front - not having to remove the entire unit to check or change a fuse! For example, some GE units have a hinged front panel - remove a couple of screws and most of the internal components can be accessed for service. This would not be possible where a countertop oven is used in a permanent installation.

(From: Roy Smith (roy@popmail.med.nyu.edu).)

I've installed a GE over-the-range microwave. It really was quite straight-forward. There is a backplate which you attach to the wall with whatever combination of lag bolts, screws, expansion bolts, etc you can get to work (i.e. wherever you can find studs, etc). It comes with a template to make this easy. The rear-bottom edge of the oven then clips onto the backplate to form a kind of hinge, and you pivot the oven up into place. There are two long bolts that run the depth of the oven near the top which you use to complete the attachment of the oven to the backplate. You then bolt it into the cabinet above it for additional security.

Taking a microwave oven overseas (or vice versa)

Microwave ovens are high power appliances. Low cost transformers or international voltage adapters will not work. You will need a heavy and expensive step down or step up transformer which will likely cost as much as a new microwave oven. Sell the oven before you leave and buy a new one at your destination.

Furthermore, for microwave ovens in particular, line frequency may make a difference. Due to the way the high voltage power supply works in a microwave oven, the HV capacitor is in series with the magnetron and thus its impedance, which depends on line frequency, affects output power.

High voltage transformer core saturation may also be a problem. Even with no load, these may run hot even at the correct line frequency of 60 Hz. So going to 50 Hz would make it worse - perhaps terminally - though this is not likely.

- Going from 50 Hz to 60 Hz at the same line voltage may slightly increase output cooking power (and heating of the magnetron). The line voltage could be reduced by a small amount to compensate. This is best done with a buck/boost transformer rated for the maximum current input to the microwave oven (usually 15 A). Alternatively, it may be possible to replace the HV capacitor with one that has about 5/6 the uF value, at the same or higher operating voltage.

- Going from 60 Hz to 50 Hz may slightly decrease output power and possibly increase heating of the HV transformer due to core losses. Using a slightly lower line voltage will reduce the heating but will further decrease the cooking power.

The digital clock and timer will likely run slow or fast if the line frequency changes as they usually use the power line for reference. Of course, this may partially make up for your change in output power! :-)

Microwave oven test-mode

(From Mark Paladino (paladino@frontiernet.net).)

Some microwave ovens have a self-test feature. This self-test is usually accessed by pressing a couple of keys on the touch pad. You can usually test things like keys, switches controller etc. Check the manual for any self-test info. Some microwaves have this information tucked in a pocket or hidden somewhere behind panels.

High frequency inverter type HV power supplies

While the vast majority of microwave ovens - perhaps every single one you will ever see - use minor variations on the tried and trusted half wave doubler circuit, a few models have been designed using solid state high frequency inverters - in many ways similar to the deflection/HV flyback power supply of a TV or monitor. This number is will likely increase as it becomes cheaper to use semiconductors than iron. It's not clear if inverter microwaves provide any real advantage in terms of performance. But there is definitely a marketing benefit and they do weigh less. :)

A typical circuit (from a Sharp microwave oven) uses full wave rectified but mostly unfiltered pulsating DC as the power to a large ferrite inverter transformer which sort of looks like a flyback on steroids. See High Voltage Inverter Power Supply from Sharp Microwave Oven. This means that the microwave output is pulsing at both 60 Hz and the frequency of the inverter!

```
      Bridge Rectifier          Inverter Transformer           Magnetron
                                       o
```

```
  H o----+---|>|------+--------+-------+    +--------------------------+
        ~|            |+      _|_ Drive )::( Filament 1T #18           |
         +---|<|---+  |       ---   25T ):: +--------------+------+    |
 115 VAC           |  |        |    #12 )::   HV Cap       |    +-|----|-+
         +---|>|---|--+        +-------+ :: +-------||-----+    | |_  _| |
         |         |           |         ::(    .018 uF    |    |   \/   |
  N o----+---|<|---+   Drive |/ C        ::(    2,400 V  __|__  |   ___  |
        ~          |-    o---|   Chopper ::( HV          _\_/_  +----|:--+
 (Interlocks and   |         |\ E        ::( 250T          | HV      |'-->
  fuses/protectors |           |         ::( #26   Sense   | diode   | uWaves
  not shown)       +-----------+            +--+---/\/\----+---------+
                                             o  |    1.2  _|_
 (Except for filament, # turns estimated)       o H1        -  Chassis Ground
```

The chopper transistor is marked: Mitsubishi, QM50HJ-H, 01AA2. It is a LARGE NPN Darlington transistor on a LARGE heatsink. :-) Others may use LARGE IGBTs or MOSFETs.

Note the similarity between the normal half wave doubler circuit and this output configuration! Base drive to the chopper transistor is provided by some relatively complex control circuitry using two additional sets of windings on the inverter transformer (not shown) for feedback and other functions in addition to current monitoring via the 'Sense' resistor in the transformer return.

It is not known whether power levels in the oven from which this particular inverter unit came were set by the normal long cycle pulse width modulation or by control over a much shorter time scale, or by pulse width modulation of the high frequency power. However, the blurb for the current line of Panasonic Genius(tm) inverter microwave ovens does boast about providing actual power continuously at each setting though I've heard it may only be down to a 1/10th, but that's close enough. Panasonic has a several models like this. I don't know what other manufacturers (including Sharp) still do. I acquired the Sharp unit in the late 1990s.

Compared to the simplicity of the common half wave doubler, it isn't at all surprising why these never caught on (what is diagramed above includes perhaps 1/10th the actual number of components in a typical inverter module, which can be seen in the photo). Except for obvious problems like a tired fuse, component level troubleshooting and repair would be too time consuming. Furthermore, as with a switchmode power supply (which is what these really are) there could be multiple faults which would result in immediate failure or long term reliability problems if all bad parts were not located. Schematics are not likely available either. And, a replacement module would likely cost as much as a new oven!

This may simply be a situation where a high tech solution might not have been the best approach. The high frequency inverter approach would not seem to provide any important benefits in terms of functionality or efficiency yet created many more possible opportunities for failure. The principle advantages claimed by the manufacturer are more even cooking and less overcooking of edges. The microwave distribution mechanism is at least as important in this regard. Another major advantage - reduced weight - is somewhat irrelevant in a microwave oven. Perhaps, this was yet another situation where the Marketing department needed something new and improved! But if it was a "must have", other companies certainly aren't jumping on the bandwagon. Possibly more have jumped off. :)

(From: John De Armond.)

Don't try to operate an inverter-based oven from a cheap generator with a less than perfect sine output. That's another excuse for the blue smoke to leak out.

In my case I wasn't about to spend that kind of money to repair an oven that barely cost that much, especially since I used it in my restaurant always on high. Therefore I yanked out all those fancy electronics and installed the transformer/diode/cap assembly from another old oven. I drilled a hole through that nice touch pad and installed an Intermatic spring-wound timer from Home Depot.

Viola, good as new and bullet-proof against nasty power.

Dangerous (or useful) parts in a dead microwave oven?

A microwave oven with its power cord cut or removed AND its high voltage capacitor safely discharged is an inanimate object. There are no particularly hazardous parts inside. Of course, heavy transformers can smash your feet and sharp sheet metal can cut flesh. And, the magnets in the magnetron may erase your diskettes or mess up the colors on your TV.

Some may feel there is nothing of interest inside a microwave oven. I would counter that anything unfamiliar can be of immense educational value to children of all ages. With appropriate supervision, an investigation of the inside of a deceased microwave oven can be very interesting.

However, before you cannibalize your old oven, consider that many of the parts are interchangeable and may be useful should your *new* oven ever need repair!

For the hobbiest, there are, in fact, some useful devices inside:

- Motors - cooling fan and turntable (if used). These usually operate on 115 VAC but some may use low voltage DC. They can easily be adapted to other uses.
- Controller and touchpad - digital timer, relay and/or triac control of the AC power. See the section: Using the control panel from defunct microwave oven as an electronic timer.
- Interlock switches - 3 or more high current microswitches.
- Heavy duty power cord, fuse holder, thermal protector, other miscellaneous parts.
- High voltage components (VERY DANGEROUS if powered) - Typical HV transformer (1,500 to 2,500 VRMS, 0.5 A), HV rectifier (12 to 15 kV PRV, 0.5 A), and HV capacitor (approximately 1 uF, up to 1,500 to 2,500 VAC (4,200 to 7,000 VDC).
- Magnetron - there are some nifty powerful magnets as part of the assembly. Take appropriate precautions to protect your credit cards, diskettes, and mechanical wristwatches. See the section: The magnets in dead magnetrons.

DOUBLE WARNING: Do not even think about powering the magnetron once you have removed any parts or altered anything mechanical in the oven. Dangerous microwave leakage is possible.

If disassembling the magnetron (or if it does this on its own for some reason), see the comments below.

(From: Wayne Love.)

I am a microwave engineer and manufacture high power magnetron (up to 10 kilowatts at 2.450 GHz and up to 100 kilowatts at 915 MHz.) Just some info. The filament in a 2.450 GHz magnetron is generally made of thoriated (about 2% thorium) tungsten. The thorium is slightly radioactive but the tungsten is generally not poisonous. The lead-in to the vacuum envelope are generally molybdenum and also relatively inert. If the vacuum tube is compromised with the filament at temperature (around 950 °C), tungsten oxide (yellowish/white coating) can also form. Generally this is not harmful but smart to avoid anyway.

(From: Sam.)

Hmmmm 100 kW. I guess I shouldn't run one of those exposed on a work bench. ;-)

(From: Wayne.)

The 915 MHz (actually 898 MHz in the UK and parts of the old eastern block countries) 100 kilowatt magnetrons are about 4 feet tall and weight a couple of hundred pounds and that is just the vacuum diode. Add a couple of hundred more pounds for electromagnet and electronic lead terminals and I am pretty sure it might crush your work bench. :) They are used primarily for large industrial processing.

The magnets in dead magnetrons

The dead magnetron you just replaced is fairly harmless. There is no residual radiation but it does contains a pair of powerful ferrite ring magnets. These can be removed without extensive disassembly and make really nice toys but should be handled with care. Not only can they pinch flesh (yes, they are that powerful) but they will suck all the bits right off your tapes, diskettes, and credit cards. If you do want to save the magnets:

- Disassemble the magnetron assembly as follows:
    - Remove the top portion of the magnetron - it is either fastened with screws or some metal tabs which are easily bent out of the way.
    - Remove the cover over the box where the filament connections are located. This usually requires peeling off the sheet metal around the edges.
    - Cut the thick copper connections to the filament near the tube itself. (The thick copper coils are RFI chokes and prevent any microwave energy from escaping via the filament circuit.)
    - Spread the frame apart just a bit and lift out the tube with heat sink fins. CAUTION: the sheet metal fins may be sharp!
    - The magnets can now be pulled off. They may need cleaning. :-(
    - The magnetron tube itself can be disassembled by grinding off the welds around the edges of the large cylinder or cutting around it outer edge near one end with a hack saw but it takes quite a bit of curiosity to make this a worthwhile exercise. There is a slight chance that the coating on the filament is poisonous so don't take chances. You don't need to get inside to remove the magnets.
- Keep the magnets a safe distance away from any magnetic media including what might be in your back pocket, mechanical wrist watches, and color computer monitors and TVs.
- Paint the magnets with plastic enamel or coat them with the stuff used on tool handles to reduce their tendency to chip. The chips are as magnetic as the overall magnet. The ferrite is basically a ceramic and fragile. Smack them too hard and they will shatter.
- Take care not to get your skin between the magnets when you bring them together since the attractive force when nearly touching is substantial.
- Store the magnets in a box packed in the center of another box with at least 4 inches on all sides. Clearly mark: powerful magnets with appropriate warnings.

Having said that, these magnets can be used to demonstrate many fascinating principles of magnetism. Have fun but be careful.

Also see the section: Magnetron construction - modern microwave oven.

Using the control panel from defunct microwave oven as an electronic timer

It is usually possible to remove just the touchpad and controller board to use as a stand-alone timer with a switched output. Be careful when disconnecting the touchpanel as the printed flex cable is fragile. With many models, the touchpanel (membrane touchpad) needs to be peeled off of the front plastic panel or the entire assembly can be removed intact.

The output will control a 10-15 A AC load using its built in relay or triac (though these may be mounted separately in the oven). Note that power on a microwave oven is regulated by slow pulse width modulation - order of a 30 second cycle if this matters. If it uses a triac, the triac is NOT phase angle controlled - just switched on or off.

Precise control of microwave oven power

For heating a casserole, the 10 to 30 second cycle time typically used for microwave oven pulse width heat control is fine. However, for other purposes, this results in unsatisfactory results. This question was posed by someone who wanted to modify the circuitry to their microwave oven to provide continuous control and a constant heating rate.

Just cycling faster (without any other modifications is not the answer). One problem is that the filament of the magnetron is turned on and off as well. This would result in a very non-linear relationship between on-time and power as the cycle became shorter and shorter.

It should be possible to put a Variac (variable autotransformer) on the input to the high voltage transformer - between the controller and HV primary. (For safety, DON'T attach it externally, DON'T bypass or disable any door interlocks, and make sure the cooling fan is always powered from the full line voltage.) The power to the filament will still be affected but there will be a range over which continuous control will be possible. My guess is that this would be between 60 and 80 percent and full voltage from the Variac will result in 0 to 100 percent of cooking power (the magnetron is a non-linear device - there is a threshold voltage below which no output is generated). However, there will be a lag as the filament heats and cools.

Where manual control is all that is needed, this approach may be the adequate.

If the filament were put on its own transformer (with appropriate insulation ratings), then instantaneous control of power should be possible using a Variac on the HV transformer primary or a phase control scheme using a triac - a high power light dimmer or motor speed control might even work. Alternatively, a triac or solid state relay can be turned on and off at the peaks of the AC (to minimize inrush) similar to the pulse width modulation that is normally used for the oven - but at a much higher frequency. This could easily be computer controlled with feedback from a temperature sensor.

In any case, you want everything else - including cooling fans - to be on the full line voltage not affected by any power control scheme or timer.

Has technology gone too far?

Don't you just hate it when your kitchen appliances have the highest IQ in the household? What more could you want? Maybe, a microwave with a robot arm to retrieve the food from your fridge or freezer! But wait, you haven't seen it all. Just what the World needs is a smart microwave. You WILL see ovens (if they don't exist already) that with the help of a barcode or Dallas ID chip on the frozen package or food container, will contact a recipe database at the Web site for the product to determine exactly how to optimally overcook it and turn it into rubber. :)

(From: Dave Marulli (marulli@rdcs.kodak.com).)

We bought a Sharp unit with the Interactive Display feature.

There is a list of common items that you might Defrost, Cook, or Reheat. You pick one of those tasks, choose a number from the list, enter the 'quantity', hit start and it picks the time and power level. There is even an 'on-line' help feature. A typical session goes like this:

```
    Button Pressed                      Screen Output
   ----------------                 ------------------------------
      CompuCook                      Enter Food Category
          1                          Baked Potato, Enter Quantity
          4                          Press Start
```

Unit turns on and starts cooking. If the little word HELP lights up, you press the HELP button and it gives you little hints like, DO NOT COVER, or CUT IN HALF, etc.

For things like CompuDefrost, you tell it what you are defrosting, how many pounds, and hit start. It will turn on for a while, then beep at you and tell you to break the pieces apart, cover the edges, etc. You do as you are told, close the door hit start and it continues until it's time for you to do some thing else.

Same idea for CompuReHeat: Tell it how many slices of pizza or bowls of pasta you want to reheat, and it sets itself up and takes off.

It even has the obligatory POPCORN button!

Another neat feature is that you can hold the start button on without setting any time and it will stay on for as long as you hold the button. This is great for melting cheese, softening butter or chocolate, etc.

But, does it run Lotus??? :-) --- sam.

(From: Steve Dropkin (sdropkin@isd.net).)

The one we bought has an LCD screen that's maybe three inches square, takes you step-by-step through anything the oven can do, and includes 600 recipes (!). While that sounds like overkill, the attraction for me was that the menu-driven interface actually seemed simpler and more inviting than the ovens with timing buttons and 24 others marked "popcorn," "baked potato," "hot dog," "frozen dinner," "beverage," "sandwich," "waffles," etc. They looked just way too busy. (Same argument I have against a lot of mainstream HiFi equipment these days. I just want to listen to the music, not reengineer the sound source ...)

(From: Andrew Webber (webbers@magma.ca).)

Our microwave has a button for popcorn. As far as I can tell, all it does is automatically set 5 minutes. The manual says to monitor the popcorn anyway since it varies based on bag size, etc. So on principal I choose 5 minutes on high and stop it at 1:45 (why not set for 3:15? because the one time I tried it the popcorn was burnt!). I can choose 5 minutes with two presses (QUICK, 5) and popcorn with two presses (POPCORN, START).

But that popcorn button sure is a good selling point! :)

Microwave ovens for non-standard applications

Occasionally, people ask questions about the use of a microwave oven to do things other than heating food. In general, these have to be taken on a case-by-case basis. Obviously, softening sticks of Dynamite is probably not to be recommended! (There actually is a reason for this - a microwave can develop hot spots - heating is not as uniform as with normal ovens. Do your dynamite softening in a normal oven).

Special kilns that will fit inside a microwave oven are apparently available to achieve really high temperatures. They consist of a ceramic (expanded alumina or something similar) insulating cylinder lined with a microwave susceptor - possibly a ferrite material. Temperatures exceeding 1000 degrees C (yellow-white heat) are possible after a few minutes on high. See for example Microwave Melting of Metals.

If any modifications are made to the oven that would compromise the integrity of the door seals or provide other places where microwave radiation could escape, then special tests MUST be done to assure the safety of the users of the equipment. The following is one such case in point:

> "My Dad and I are using a microwave oven to heat oak strips by passing them through the microwave field of a 1000W oven. We cut out squares (4"x 4") in the glass front and metal back of the oven to allow these strips to pass through the field. I am concerned about potential microwave leakage of a harmful nature."

Geez!!! You guys are out of your collective mind. Sorry, having said that I feel much better. :-(

My first recommendation (though this is too weak a term) would to not do this.

My second (and up to N where N is a very large number) recommendation would be not to do this.

However, if you insist, use a good conductive sheet metal such as copper or aluminum to reduce the size of the opening as close to the material as possible. The wood stock will tend to reduce leakage while it is in place but the opening will leak like crazy when there is nothing in the hole. The sheet metal must be in electrical contact with the mesh in the door and the metal back. The smaller the opening, the less will be the leakage. Also, make sure there is always a load in the oven (a cup of water, for example) to keep the magnetron happy.

Next, borrow an accurate microwave leakage detector. A large appliance repair shop or electronics store may rent you one if you are persistent enough. Use this to identify the safe limits front and back. Label these and don't go closer while the oven is in operation. The operators may have to remain further away or some additional shields may needed if these distances are not satisfactory. The leakage detector or microwave field strength meter should come with information on acceptable power limits. It is something like 2 mW per square cm a foot or so from the oven - check it out. However, there is no assurance that even this limit is safe.

CAUTION (In addition to the loony nature of this entire project!): Since the leakage you encounter may be orders of magnitude greater than what is typical of even a misaligned microwave oven, start with the probe at a distance of a few feet and slowly move it closer while watching the meter or readout. Don't set it next the opening as you hit START! This will prevent the possibility of damage to the expensive leakage tester (which could be costly) and exposure risk to you as well.

The only known confirmed danger from microwave radiation is from internal heating effects. The eye is particularly sensitive to this and it doesn't take much of an increase in temperature to denature the tissue of the central nervous system (i.e., scramble your brain). The human body does not have an adequate warning system since nerve endings sensitive to heat are somewhat sparse. Thus, while the dangers may be overstated, it doesn't make sense to take chances.

What is wrong with radiant heat???

(From Barry Collins (bcollins@mindspring.com).)

You did the right thing to discourage people from breaching the integrity of a microwave oven, because there are so many factors involved that one has to assume personal (or property) injury (or damage) may result from such actions.

I personally don't feel uncomfortable with what the person was doing, provided they had taken reasonable precautions (too numerous to list). Power does fall off with the square of the distance and microwaves, barring any reflective surface, are very directional by nature. Just don't stand in front of the source. (I met one of the Japanese engineers who had unintentionally placed his head in a test oven that was working. He reported warmth, but no lasting damage, aside from the resulting joke.) Field density and exposure time is a large factor. One tends to remove one's hand when one senses heat. I think the story goes that this was how the heating affect was originally discovered.

The number one precaution I've always held near and dear to me is to protect one's eyes. The Narda manual has multiple warning in it about this. The aqueous membranes of the eyes are perfect absorption material for stray microwaves. This can happen much faster than with fleshy parts of the body and don't heal anywhere near the way a flesh injury does. It is this that you might want to point out in your FAQ's.

Short course on Amana

(From: Charles Godard (cgodard@iamerica.net).)

Everything depends on "Air Flow". If the stirrer does not turn, you will always get a "Hot! spot" on the left bottom of the door. In addition the stirrer bearing will sometimes arc and may melt at the spots where it arcs.

If your blower is running up to speed, remove the cover and replace the foam gasket material. This forces air over the stirrer when the cover is replaced. If stirrer still does not turn, remove the grease shield and check the stirrer for burns that are causing it to stick. If this is ok or you correct it and stirrer still does not turn, then replace the grease shield with a later model that looks almost the same as the original, but has one small modification which you will see when you compare the two.

Never let one go out of the shop unless the stirrer is turning. It will soon be back unless all they do is heat coffee. Next time it may be a cavity or magnetron overload that has opened due to the stirrer not turning.

It's good work on a quality product. I wish I had a hundred restaurant customers using them. The older Amana's power stays near 1,500 watts forever. Retail customers are junking them because of $100 - to $125 repair bills. What a waste!

Computer system near microwave oven?

> "Can placing my microwave oven in close proximity to my computer and printer do any damage to either of them? The back of the oven would be right next to the printer and about 16 inches from the computer. I have gotten conflicting answers from the guy who rebuilt my computer and the guys at Radio Shack."

Did the kids at Radio Shack even understand the question??? :)

Your request is certainly a bit unusual. My feeling is that it should be fine. The problem would more likely be the magnetic field from the large transformer in the microwave oven causing interference on your monitor (wiggling, jiggling, shimmering, etc. due to its effect on the electron beams in the CRT). There should be no significant microwave leakage from the oven, especially the rear. Keep in mind that there is a computer of sorts inside the microwave controlling it!

However, you will need separate grounded electrical circuits for the microwave and computer equipment if you intend to ever use them at the same time.

Why Microwave-Safe Containers Get Destroyed

You probably have a cabinet full of so-called microwave-safe containers that look like they have been exposed to damage from a nuclear explosion. Why? It probably comes down to unequal heating of the contents or heating continuing long past the point where boiling takes place. I would assume that putting a microwave-safe container in an oven with a cup of water in a separate container wouldn't result in any damage to the microwave-safe container. But if the contents of the microwave-safe container are being heated, then some parts will get much hotter than others resulting in local melting and other damage. I doubt it is the microwave radiation itself doing anything to the material of the container directly and complaining to the oven manufacturer isn't likely to be very satisfying. :)

- Back to Microwave Oven Repair FAQ Table of Contents.

Service Information

Advanced troubleshooting

If the solutions to your problems have not been covered in this document, you still have some options other than surrendering your microwave to the local service center or the dumpster.

Unlike most other types of consumer electronic equipment, a service manual is rarely required. A sufficiently detailed schematic is nearly always pasted to the inside of the cover and includes all power components, interlocks, fuses, protectors, and wiring. This is entirely sufficient to deal with any problems in the microwave generator. No adjustments or alignment should even be required so detailed procedures for these are not needed.

However, when tackling electronic faults in the controller, a service manual with schematics will prove essential. Whether these are available depends on the manufacturer. For legal reasons, some manufacturers are reluctant to sell service information or replacement parts for microwave ovens. They are concerned with litigation should an unqualified person be injured or killed.

Suggested Reference

I know of at least one book dealing specifically with microwave oven repair. It is very complete and includes many actual repair case histories. There is a good chance that your specific problem is covered.

1. Microwave Oven Repair, 2nd Edition
   Homer L. Davidson
   TAB Books, a division of McGraw Hill, Inc., 1991
   Blue Ridge Summit, PA 17294-0850
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Cost of repair parts

Assuming you have located one or more bad components, the question is whether an oven that is a few years old is worth fixing. Typical parts cost for generic replacements:

- HV diode: $2-5 (except for the bolt-on variety which can range up to $50. It should be possible to replace these with the $2 variety with wire leads);
- Power fuse: $.40.
- HV Capacitor: $10-20.
- Magnetron: $30-100. Common generic replacements are $30-40.
- Overtemperature thermostat (thermal protector): $4.50.
- Interlock Switch: $2.50.
- Triac: $12.00 (unless original replacement in which case you will need to take out a mortgage - try the generic variety).

Parts suppliers like MCM Electronics can provide these components to fit the vast majority of microwave ovens.

Touchpads and controller parts like the microprocessor chip are usually only available from the manufacturer of the oven. Prices are high - a touchpad may cost $30 or more.

Sensors and other manufacturer specific parts will be expensive.

While the HV transformers are fairly standard, they are not readily available from the common replacement parts sources. However, they do not fail that often, either.

Here is one place that seems to stock some: AMI Parts, Eagle Grove, IA. Voice phone: 1-800-522-1264. However, they won't be cheap - expect to pay $50 or more!!! In addition, MCM Electronics now lists at least one Goldstar model replacement.

With the prices of microwave ovens dropping almost as fast as PCs, a few year old oven may not be worth fixing if the problem is a bad magnetron or touchpad. However, except for a slight decrease in power output as the oven is used over the years and the magnetron ages, there is little to go bad or deteriorate. Therefore, you can expect a repaired oven to behave just about like new.

Interchangeability of components

The question may arise: If I cannot obtain an exact replacement or if I have another microwave oven carcass gathering dust, can I substitute a part that is not a precise match? Sometimes, this is simply desired to confirm a diagnosis and avoid the risk of ordering an expensive replacement and/or having to wait until it arrives.

For safety related items, the answer is generally NO - an exact replacement part is needed to maintain the specifications within acceptable limits with respect to line isolation, radiation emission, and to minimize fire hazards. For microwave ovens such parts include the power fuses, interlock switches, and anything else that could potentially lead to microwave radiation leakage - like a magnetron which did not fit the waveguide properly.

Fortunately, while an exact match may be required, it doesn't have to be from the original manufacturer - most parts are interchangeable. Thus the organs from that carcass may be able to provide renewed vitality to your ailing microwave.

Here are some guidelines:

1. Fuses - exact same current rating and at least equal voltage rating. This will probably be a ceramic 1-1/4" x 1/4" 15 or 20 A 250 V fast blow type. For the repair, use an exact replacement. For testing only, a similar type may be used.

2. Thermal protectors - same temperature and maximum current rating. You must be able to mount it securely and flush against the same surface as the old one.

3. Interlock switches - must have the same terminal configuration and at least equal current rating. Of course, a secure fit is very important as well for it to perform its safety function. Many of these are interchangeable.

4. HV capacitor - similar (within 5%) and at least equal working voltage. Note that the working voltage rating of these capacitors is not consistent with the way capacitors in other electronic equipment are specified and is usually the RMS voltage of the AC input from the HV transformer. Therefore, it is not possible to substitute something from your junkbox unless it is from a microwave oven. In addition, this is one situation where higher capacity (uF) is not better. The power output is related to capacitance. Thus, the value should be matched fairly closely or else other parts may be overloaded. However, a smaller one can be used for testing.

5. HV diode - most of these have similar electrical ratings so a substitution is possible if you can make it fit physically. This would be particularly desirable where your oven has one of those chassis mount $50 dollar varieties - it may be acceptable to use a $2.75 generic replacement.

6. Relays and triacs - substitutes will generally work as long as their specifications meet or exceed those of the original. Creative mounting may be required.

7. Magnetrons - a large number of microwave ovens use the same basic type but the mounting arrangement - holes vs. studs, orientation of the cooling fins, etc., differ. You can safely substitute a not exact match for testing purposes IF you can make it fit the waveguide securely without gaps. However, if the cooling fins end up being on the wrong side, it will heat up very quickly - 50% of the input power goes to heat - and will not be suitable as a permanent replacement.

8. HV transformer - same (within 5%) voltage and at least equal current rating. Mounting should not be a problem but don't just leave it loose - you could end up with a disaster.

9. Fans and motors - speed/power and direction must match and mounting must be possible. Speed isn't so critical for a turntable but for a magnetron cooling fan, inadequate air flow will result in overheating and shutdown or failure. Common shaded pole type motors may be interchangeable with other appliances or if a mounting arrangement can be cobbled together.

10. Mica waveguide cover - cut to match.

11. Turntable and mode mixer components - if they fit, use them.

12. Light bulb - similar ratings and base.

13. Temperature sensors, thermistors, etc. - depends on the particular model.

14. Mechanical timers - compatible switching and mounting arrangement.

15. Cordsets - must be 3 wire heavy duty grounded type. Make sure the replacement has at least as high a current rating as the original. Observe the color code!

16. Controller and touchpad - small parts like resistors, diodes, capacitors, and so forth can often be substituted. Forget about the controller ICs or display. The touchpad is likely to be custom both electrically and physically as well unless you have a similar model microwave to cannibalize.

Can I substitute a slightly different HV capacitor for a blown one?

It is not always possible or convenient to obtain an exact replacement high voltage capacitor. What will the effects be of using one that is a slightly different value?

First, the voltage rating must be at least equat to that of the original. It can be higher but never never lower or you will probably be replacing it again in the very near future.

Now for the uF rating:

Unlike a conventional power supply filter capacitor, the capacitor in a microwave is in a voltage doubler and effectively in series with the load (magnetron). Therefore, its value **does** have an impact on output power. A larger capacitor will slightly increase the output power - as well as heat dissipation in the magnetron. Too small a capacitor and the doubler will not produce full output.

As an example, the impedance of a 1 uF capacitor at 60 Hz is about 2.5 K ohms. The cap is in effect in series with the magnetron. A 1 kW magnetron running on just over 3 kV RMS is about 10 K ohms. These are really really rough calculations.

Thus the power difference is not a straight percent for percent change - I estimate that it is about a 1:4 change - increase the capacitor's uF rating by 10 percent and the power and magnetron heat dissipation will go up by 2.5% (assuming the relationship is linear right around the nominal value). I have not confirmed this, however.

Therefore, I would say that using a capacitor with up to a 10-15% difference (either way) in uF rating is probably acceptable but a closer match is better.

Obtaining replacement parts for microwave ovens

For general electronic components like resistors and capacitors, most electronics distributors will have a sufficient variety at reasonable cost. Even Radio Shack can be considered in a pinch.

However, places like Digikey, Allied, and Newark do not have the specialized parts like magnetrons, HV capacitors and diodes, interlock switches, thermal protectors, etc., needed for microwave oven repair.

Your local appliance distributor or repair parts outlet may be able to obtain an exact replacement or something that is an eceptable substitute. However, the cost will be higher than for generic parts from the places listed below if they carry what you need.

Going direct to the manufacturer is a possibility but expect to pay more than might be charged for generic replacement parts by an independent company. Also, some places like Sears, may refuse to sell you anything microwave oven related due to safety concerns - unless they are convinced you are a certified repair technician, whatever that might mean. Their prices are inflated as well.

Another alternative is to determine who actually made your oven. This is obvious with name brands like Panasonic and Sharp. However, Sears doesn't manufacture their own appliances, but an inspection inside may reveal the actual manufacturer. Then, go direct to the horse's mouth. Many companies will be happy to sell service parts but availability may be a problem on older ovens. I had to give up on a Sharp microwave/convection oven that was 15 years old because specialized replacement parts were no longer available from Sharp.

Note: I have heard that in other parts of the world, there may be restrictions on who can actually purchase microwave oven parts other than things like light bulbs, turntables, and standard door switches. In the U.S., certain companies (like Sears) may set their own rules - you have to convince them that you have at least the intelligence of an average carrot and possibly sign a 100+ page document written by too many lawyers. :)

Sources for replacement microwave oven parts

See the document: Major Service Parts Suppliers for some companies that I have used in the past and others that have been recommended. They may include microwave oven parts in their catalog but don't specialize in them. Also see the "Microwave Oven" sections of Sam's Neat, Nifty, and Handy Bookmarks.

The following suppliers have web sites with on-line catalogs and list a very extensive selection of microwave oven parts. There is a chance that they may not want to sell to the general public. I suppose this may be due to several factors including the potential liability issues, complaints/attempts to return parts when a repair doesn't work, and the small quantities involved. However, it is definitely worth checking as the public web sites implie a desire to deal with the entire Internet community.

- Global/MPI/All Appliance Parts
  Phone: 1-800-325-8488
  Web: http://www.allapplianceparts.com/

  Their web site includes a very extensive selection of microwave oven parts. For example, nearly 50 different magnetrons are listed along with little photos of each!

- AMI (Appliance Maintenance International)
  U.S. Phone: 1-800-522-1264
  U.S. Fax: 1-800-442-3601
  Int. Phone: 1-515-448-5311
  Int. Fax: 1-515-448-3601
  Email: ami@amiparts.com
  Web: http://www.amiparts.com/

  Distributor of consumer and commercial microwave oven parts. Extensive on-line catalog of microwave oven parts with on-line parts lookup and ordering.

Here is another one:

- Electronix, Corporation
  Web: http://www.electronix.com/

  Magnetrons, interlock switches, lamps, glass trays, diodes, thermal fuses, couplers, latches, rivets, stirrers, fans, waveguides, more... Also: Techweb, $6/month.

The following company will definitely not sell you anything but should be able to provide the name of a local appliance parts distributor.

- QB Products
  Phone: 1-800-323-6856

  Master distributor, they sell only to appliance and electronics parts distributors like Marcone, Tritronics, Johnstone, etc. You can call them to find the nearest distributor.)

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