Pat Hawker's Technical Topics

"KEYBOARD INJURY DOES NOT EXIST"

KEYBOARD/MORSE KEY users must have raised their eyebrows when, within a few days of the publication of the November *TT* item "RSI, Keyboard cramp & glass arm", they were told by a High Court judge that the condition of repetitive strain injury does not exist and that keyboard users forced to give up their jobs because of aching muscles and joints were "eggshell personalities who needed to get a grip on themselves"!

That judgement may of course be overturned on appeal and in the meantime, it remains prudent for those using keyboards and keys over long periods under conditions of stress to minimise the risk of falling victim to "non-existent" [yet well documented in the 1930s by Colonel Prynne, a retired Chief Medical Officer of the GPO] telegraphist's cramp that does not appear to be confined to "eggshell personalities".

One *TT* reader who believes that sensible precautions should be taken to minimise the risk of RSI is Bob Mersh, G8JNZ, who has been a professional RTTY telegraphist for close on 30 years and in similar work as a police controller for the past four years; a job that can be extremely stressful – taking calls from distressed or irate members of the public or controlling a vehicle or foot chase or dealing with bomb incidents etc. He writes:

"In my control room there are three operators coping with seven telephone lines, a radio system and three computer systems – often calls come in on all of these at the same time. At certain times of the day the telephone lines never stop – a continuously stressful environment.

"Our Health & Safety people recommend a 'stress break' of ten minutes in every hour which I endeavour to practise although work circumstances often dictate otherwise. I think this practice is a good idea and should be followed by amateur computer buffs who sit straining over the beastly thing for hours at a time. Go for a wander, make a cup of tea/coffee and, importantly, have a good stretch of one's limbs and let the mind relax.

"A comment on Fig 2 of the November *TT* depicting 'The right way to work'. A simple rule of thumb to gauge a good operating position is that the forearm should be horizontal as this does not put too much strain on the wrist and fingers. I was taught this at the Post Office training school. However, I have not previously heard of the recommendation that the upper arm is kept vertical and would suggest that unless one is able to tailor-make the operating position this may not be possible. For those of us with beer bellies it will be an impossibility! Let your arm hang vertically and your forearm horizontally and see where your hands end up unless you have extraordinarily long forearms.

"Fig 2 has the screen at the correct height but does not stress this in the notation, merely saying 'tilting screen'. The point is that the screen should be positioned only slightly below eye height so that one does not have to lower or raise the chin making for an unnatural position of the head, giving rise to neck-ache.

"It is also felt that VDUs should be placed sideways-on to any windows to reduce glare. My control room has indirect fluorescent light which is bounced off the ceiling by a strange suspended structure, rather like plastic guttering with the tube laying in it. It works very well and gives a nicely diffused lighting on a dimmer control of course . . . . Indirect, and somewhat dimmed lighting is infinitely preferable to the 100W bulb in the ceiling lamp which illuminates many shacks.

"There are varying views on the usefulness of polarizing filters. The VDUs in our control rooms have special anti-glare glass on the CRTs and are reasonably non-reflective. For my own VDU, however, I have fitted a good quality American glass polarizing screen which is a definite improvement and makes the colour screen less harsh on the eyes.

"My personal theory as to why RSI seems to strike at VDU operators is that modern keyboards are harder on the fingertips than the old fashioned sprung keys of a typewriter or teleprinter with a long travel. On most teleprinters the keys never had to be depressed their full length before activating the print mechanism. Modern computer keyboards come to an abrupt halt at the bottom of a short travel and are somewhat akin to drumming ones fingers on a table top for ten minutes. [This could also explain the reason why Col Prynne found that glass arm was seldom experienced in the USA with their different design of manual Morse keys – *G3VA*]

"To sum up, my own experience has shown that the *TT* advice to keep calm in front of the machine is sound. Because I use a computer for my living *and* when I come home, I have a strict rule in the house: the minute I start to feel irritated or even minutely stressed by the beast it gets turned off and I go and do something else. It's not worth suffering mental stress over a hobby. I get paid for the stress of my job!"

JUNK BOX CROWBAR

GEOFF SWITZER, VK2SR, in *Amateur Radio* (November 1993, p15) shows how an effective over-voltage crowbar can be added to a high-current 13.8V PSU without the use of an expensive heavy-duty silicon controlled rectifier (SCR) by anyone with a junk box stock of rugged transistors such as the 2N3055. The arrangement he adopts **(Fig 1)** is for an over-voltage to fire a light-duty SCR which then turns on as many power transistors as needed to blow the fuse quickly and reliably.

VK2SR suggests that a current of 3A per 2N3055 would be suitable (he uses eight 2N3055s for his highest current PSU). Since they conduct for only as long as it takes to blow the fuse no heat sinks are necessary. He writes:

"The sensing circuit is conventional and the 200Ω resistor could be a preset of, say, 500Ω to adjust the protection voltage. The values shown sense an over-voltage of 14.5V. The 180Ω base resistors are desirable and can be found in many junk boxes. Some care should be taken in selecting the 15kΩ and 250Ω resistors across the incoming supply. These values provide a standing bias to the 2N3055s which should draw only a few mA for the group and should therefore stay cool.

"When fired, the C196 SCR effectively short-circuits the 15kΩ resistor and the whole input voltage, say 25V, is applied to the bases of the power transistors. At the same time the 250Ω resistor is placed directly across the supply and will carry 100mA until the fuse blows. This should be only a few milliseconds but the power dissipated for this time is 2.5W. The 0.1μF capacitor on the C106 gate prevents false spikes. A smaller value will reduce the time constant.

"The idea is presented as a basis for experiment but could provide a valuable outboard attachment to commercial PSUs which do not include over-voltage protection."

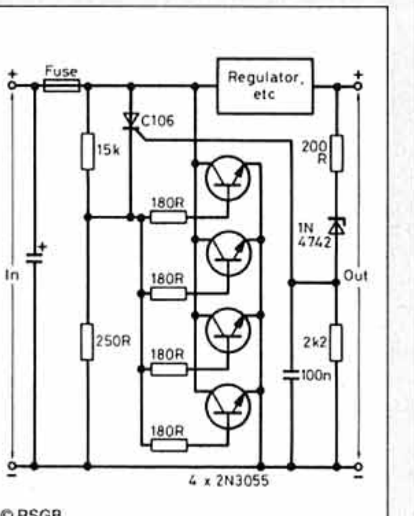

Fig 1: The 'junk box crowbar' as described by Geoff Switzer, VK2SR.

CRYSTAL FILTERS FOR HIGH-PERFORMANCE MIXERS

THE *TT* ITEM ON 'G3SBI's high performance mixer' (October 1993, pp55-56 with correction to Fig 3 in the November *TT*, p48) referred briefly to the problem that as the intercept point of the mixer is raised, a limitation to overall performance of the receiver is likely to be set by the linearity of the crystal filters available on the amateur market.

This was also mentioned in the September *TT* in connection with the N6NWP mixer; as a result of which Peter Chadwick, G3RZP, wrote: "IMD in filters should not come as a surprise. It was first mentioned in a paper by Malinowski and Smythe of Motorola in a paper at the 1973 Frequency Control Symposium: the next known mention was in *TT* in July 1977, p533 in a letter I wrote which appeared under the heading 'Receiver IMD and crystal filters' and which began "We all like to think that quartz crystal filters are passive, linear, reciprocal, two-port networks. In practice they are two-port and passive; but they are far from linear or reciprocal! Typically an HF SSB crystal filter will have an intercept point of +15 to +18dBm. Turning it round will often alter the intercept point. The IMD products in the passband are more of a problem than those removed by 10 or 20kHz . . . ."

"Since then, the problem has become 'recognised' professionally. Incidentally, SAW filters are very good because they don't stress the quartz, while transformers have no effect unless they are badly designed. The main cause of IMD appears to be the electric field stressing the crystals beyond the point where Hooke's Law holds, and this explains why higher frequency filters are worse than low-frequency filters; the crystal is thinner, so the volts/mm exceeds the point where Hooke's Law applies at a lower voltage.

"A more pertinent point in connection with the latest high-performance mixers is whether their good intermod performance can be used in practice. In a well-designed receiver, the IF selectivity, the phase noise and the IMD limited instantaneous dynamic ranges should be the same. Thus in a receiver with a 10dB noise figure, a 2kHz-wide IF has a noise floor of −131dBm. If the intercept figure is +40dBm, two signals at −17dBm will produce an IMD product at the noise floor. For the phase noise from a 17dBm signal to equal the noise floor, the phase noise must be 147dBc/Hz (this is derived from the intermod ratio (114dB) plus the bandwidth ratio – in this case 33dB. Getting −147dBc/Hz from an HF/VHF oscillator (especially a synthesizer) is not easy, particularly close in, such as at 20kHz spacing, even if you spend £10,000 on a good signal generator! So extremely good mixer performance is not in practice usable: the designer is up against the classic problem of improving one thing and then needing to improve another."

Colin Horrabin, G3SBI, accepts that if the performance of his H-mode mixer (October *TT*) is to be translated into a practical super-linear receiver then new thinking must be applied to both the IMD performance of crystal filters and to reducing the phase-noise of synthesized oscillators (with the more ready availability of direct-digital-synthesis (DDS) chips). As a start he has been investigating the performance of 9MHz post-mixer low-loss crystal ladder filters. The following notes are based on his report of this work carried out at the SERC Laboratory:

The H-mode FET switching-mode mixer has been shown to be capable of a +53dBm input intercept. However, experimental measurements have also shown that the input intercept of budget-priced half-lattice-type crystal filters available in the UK were not up to this performance but that the ladder-type filter might give better performance, although at that time no detailed measurements had been made. He writes:

"A number of stock 9MHz crystals (ref A164A) were purchased from IQD Ltd (Crewkerne, Somerset). This crystal is specified as 9MHz with 30pF parallel capacitance and is in an HC49 holder. Measurements have shown that series resonance is about 8.9975MHz so that ladder filter designs need a series capacitor for each crystal to move the passband centre frequency to exactly 9MHz. An important measurement showing the high quality of these crystals is that the series resistance is typically under 9Ω enabling very low-loss ladder filters to be constructed: less than 1dB insertion loss for 2.5kHz bandwidth, −60dB 15kHz, ultimate attenuation −80dB, Rt 450Ω.

"Measurements made on a number of ladder filters of different bandwidth using these crystals have enabled a typical input intercept for the filter of +40dBm to be achieved with input signals of 0 and +10dBm (still showing a 3:1 slope on a log plot). This is about the same as good commercial 9MHz SSB filters made for the amateur market by IQD Ltd. If

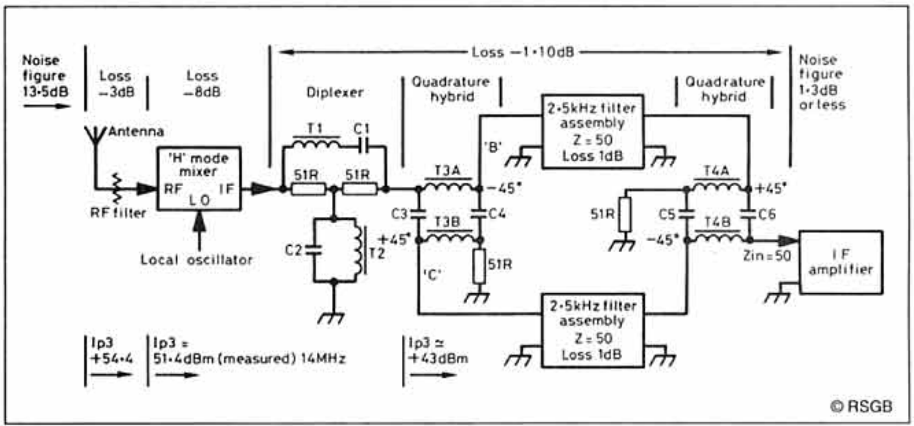

Fig 2: High-performance front-end based on the G3SBI, H-mode mixer and low-loss 9MHz crystal-filter system without a post-mixer amplifier. 13.5dB noise figure. Component details: C1, C2 330pF + 18pF Suflex. C3, C4, C5, C6 150pF + 15pF Suflex. T1, T2 (0.88μH) 16t of 0.5mm (Bicelflux RS Components) wire on Fairite T50-10 toroid (Cirkit Components). T3A, T3B, T4A, T4B (0.88μH) 16 bifilar turns of 0.31mm Bicelflux enamelled copper (RS Components) on T50-10 toroid (twist wires together using hand drill to a twist of about 1 turn on 0.1inch). The 2.5kHz filter assembly is shown in Fig 3.

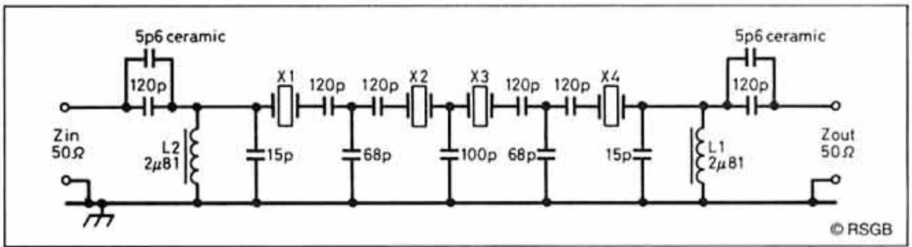

Fig 3: 2.5kHz crystal filter assembly (SSB). Components X1, X2, X3, X4 IQD (Crewkerne) stock No A164A 9MHz 30-pF parallel resonance HC49 holders. All capacitors except 5.6pF ceramic 2.5% Suflex. L1, L2 (2.81μH) 31 turns of 0.31mm dia Bicelflux wire (RS Components) on Fairite T37-6 toroids (Cirkit Components).

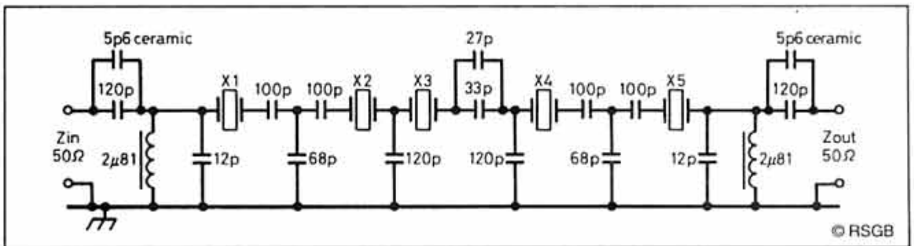

Fig 4: Five-section ladder filter (SSB). Performance −6dB at 2.2kHz, −60dB at 8.5kHz, insertion loss 1.4dB, ultimate stopband −95dB. Components X1-X5 IQD Stock No A164A (9.0MHz in parallel with 30pF). All capacitors 2.5% Suflex except those shown as ceramic. Inductors (2.81μH) 31 turns 0.31mm dia Bicelflux enamelled copper (RS Components) on T37-6 toroids (Cirkit components).

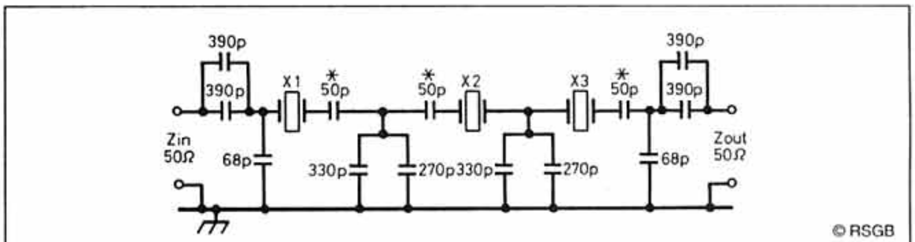

Fig 5: Three-section ladder filter (CW). Performance −6dB at 400Hz, −60dB at 4kHz, insertion loss 4.0dB, ultimate attenuation −90dB. All capacitors 22.5% suflex. Capacitors marked * adjust the pass band centre frequency, in this case 8.9993MHz which is the centre frequency of a lattice filter to be used further down the IF chain. A fixed capacitor plus ceramic variable could be used.

such a filter were used with the H-mode mixer plus a 10dB-gain post-mixer amplifier, the effective mixer input intercept would be reduced from 53dBm to about +38dBm. A better approach is to eliminate the post-mixer amplifier and instead go straight from the mixer into a home-made ladder-filter quadrature hybrid assembly as shown in **Fig 2**. The quadrature hybrid and diplexer system will always present a 50W termination to the mixer, masking the impedance changes of the crystal filter with frequency. Using the design approach shown in Fig 2 enables an antenna input intercept of about +54dBm for a noise figure of 13.5dB to be achieved, giving a two-tone dynamic range of 120dB for a 2kHz bandwidth. This could be increased to about +56dBm if crystals of better intermodulation performance could be obtained, but this slight improvement would not really justify the likely cost compared with the stock IQD crystals used.

"Ideally, the output load to the low-noise post-filter IF amplifier should be of better shape-factor SSB and CW filters than can be expected from low-loss ladder filters. However, if this amplifier could be configured as a cascode-connected dual JFET, AGC could be applied fairly easily since the amplifier itself is likely to have an output intercept of some +30dBm. If the gain were 20dB its input intercept would be +10dBm so that coming down the slope of the ladder filter by 30db (with a filter input intercept of +40dBm), the antenna intercept figure would be +54dBm for interfering signals more than 3kHz off the receiver tune frequency using a four-section SSB ladder filter. Performance would degrade closer to the tune frequency giving an in-band intercept of about +20dBm at the antenna. This approach could prove an acceptable compromise to avoid the complication of high-intercept amplifiers based, for example, on 7GHz transistors with feedback and PIN diodes for AGC control.

"Improvements to the close-in intercept figures for both SSB and CW could be obtained by having post-mixer ladder filters with selectable bandwidth. It is possible that a five-section SSB ladder filter could be standard (1.4dB loss) with a 600Hz ladder for CW (3dB loss). However it should not be forgotten that a local oscillator system with compatible phase-noise performance (better than 150dBc/Hz) would be needed if this degree of close-in signal path is to be achieved.

"All of the ladder-filter designs used for these measurements were based on the information in *Amateur Radio Techniques*, 7th edition, pp68-69 [*ART7* is £6.38 to members, plus postage, see *Book Case* pages – *Ed*] stemming from an article by J Pochet, F6BQP, in *Radio-REF* (May 1976) and are maximally flat designs. Jack Hardcastle, G3JIR has found that the original theoretical work used by F6BQP was done by J E Colin (France)

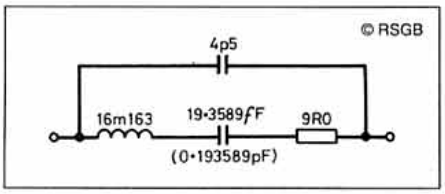

Fig 6: Typical parameters for an IQD A164A 9MHz crystal.

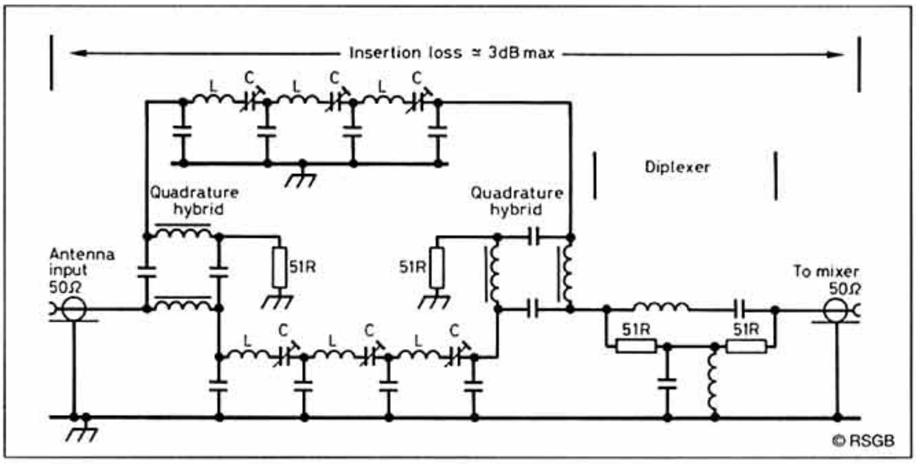

Fig 7: Antenna input filter. One circuit per band is required. Note that the bandpass filters are ladder networks with the capacitor coefficients with impedance the same as for the crystal ladder filters. L/C ratio determines bandwidth. Up to four sections of ladder could be used.

whose paper gives coefficients for the capacitors for up to six crystal ladders (F6BQP provided coefficients for only up to four crystals). In terms of insertion loss, the four crystal units proved the best in terms of loss per crystal used, but a five section filter is probably the best compromise for insertion loss versus shape factor. **Fig 3** shows a four-crystal 2.5kHz SSB 9MHz filter in which a parallel L network is used to obtain the 50Ω match. A five-section filter with 2.2kHz (-6dB) bandwidth is shown in **Fig 4**. A CW roofing filter is shown in **Fig 5**.

"All of these filter designs were first computer-simulated using a schematic entry package, Microcap 3. It was gratifying to find that the measured results were identical to the simulation. The crystal parameters were obtained by measurements on a Hewlett Packard 4195a network analyser with an equivalent circuit-function facility. The individual crystal parameters used for simulation are shown in **Fig 6**.

"From this work it is possible to conclude that a low-insertion-loss crystal filter is necessary (ideally less than 1.5dB) if it is to be used immediately following an H-mode mixer in order to avoid a noise-figure penalty. The SSB ladder filter described has the required low loss. To improve on this would require filters with better shape factors so that the intercept performance of the post-filter amplifier would be of less importance. Some work now needs to be done on a cascode amplifier to confirm that a noise figure of 1dB can be achieved with some 20dB gain for an output intercept of +30dBm. This approach would lead to a relatively simple and low-cost front-end of high performance. If a pre-mixer RF amplifier were to be used to provide increased sensitivity, a push-pull design similar to that shown in Fig 7 of the September *TT* would be needed to give a high output third-order intercept.

"The measured mixer input intercept performance on 14MHz when used with the circuit shown in Fig 3 is +51dBm, a reduction of only 1.5dB over a mixer output terminated by a 50Ω resistor (straight into the spectrum analyser). The question of the antenna input filter design has been investigated and it is likely that two identical LC filters coupled through quadrature hybrids and followed by a diplexer would be needed for each HF band (**Fig 7**) to maintain a broadband 50Ω impedance match to the input of the H-mode mixer. Alternatively a single LC filter followed by a diplexer could be tried. However, there would be impedance variations at the edge of the filter passband, so that a 20kHz two-tone test may be satisfactory yet tones at 1MHz separation may show poor intermodulation performance. The question of implementing a low phase-noise local oscillator remains to be addressed if full advantage is to be taken of the excellent signal-path dynamic range shown to be possible.

RECYCLING COMPONENTS

I SUPPOSE THAT MOST of us who entered amateur radio in the era of valved equipment soon came to appreciate the pleasure that stems from having well-filled junk boxes of recycled components recovered from discarded radio and TV receivers. These could (and can) be used to build the tolerant circuits of CW and AM transmitters or simple HF receivers. War surplus gave us the opportunity to turn swords into ploughshares for many years! It comes as a surprise that so many of later generations seem to believe that faulty electronics is now a consumer disposable - admittedly, recovering parts from crowded printed circuit boards and especially those tiny surface mounted devices is not as easy as in the days of metal chassis construction.

However, Gordon Sweet in an article in *Vital Spark* (the monthly journal of the Hastings Electronics and Radio Club) June 1992 wrote enthusiastically on the continuing possibilities of 'Recycling Components' as the following extracts show:

"In this age of increasing environmental awareness I find it a great shame that more is not done to reclaim components from faulty and disused equipment, especially among the amateur experimenters. I have little sympathy for those buying equipment at our local junk sales for a pound or two, who complain that it does not work, when the value of the components is ten times what they paid for the lot in the first place.

"Most of my collection consists of such gear, some obtained as job lots. I consider it a tragedy to see someone present a shopkeeper with a long list of components re-