# SECTION IV

# PRINCIPLES OF OPERATION

## 4-1. SIMPLIFIED DESCRIPTION

4-2. The HP 432A Power Meter consists of two major sections: the bridge and meter logic assemblies. The instrument also contains an auto zero circuit which provides for automatic zeroing on any range. A simplified block diagram of the HP 432A is shown in Figure 4-1.

4-3. The bridge section contains circuits which form two self-balancing bridge circuits when a suitable thermistor mount is connected to the 432A. Each bridge is automatically brought to balance by the action of a high gain dc amplifier feeding power to the top of the bridge. The voltage at the top of the RF bridge, $V_{RF}$ is responsive to both input RF power and ambient temperature changes. The voltage at the top of the compensation bridge, $V_{COMP}$ is responsive only to ambient temperature changes. Knowing $V_{RF}$ and $V_{COMP}$, the RF power can be calculated.

4-4. The meter logic section processes $V_{RF}$ and $V_{COMP}$ to produce a meter current proportional to RF power. The sum ($V_{RF}$ + $V_{COMP}$) controls the width of 5 kHz pulses. The difference ($V_{COMP}$ - $V_{RF}$) is chopped, amplified and fed to an electronic switch actuated by the controlled width pulses. Therefore, the meter current is pulses of variable height and width with the meter indicating the average current. (This process produces a meter current proportional to ($V_{RF}$ + $V_{COMP}$) ($V_{RF}$ - $V_{COMP}$). Paragraph 4-10 explains why this is necessary.

## 4-5. FUNCTIONAL BLOCK DIAGRAM

4-6. A functional block diagram of the 432A power meter is shown in Figure 4-2. The instrument comprises two major assemblies: bridge assembly A1 and meter logic assembly A2. Auto zero circuit A1A1, which provides for automatic zeroing of the instrument, is included as part of logic assembly A1.

4-7. The thermistor bridges are biased with direct current from the bridge amplifiers. Each bridge amplifier supplies enough heating current to bring the thermistor resistance to 100 or 200 ohms, depending upon the setting of the MOUNT RESISTANCE switch on the 432A. If one of the thermistor bridges is unbalanced due to incorrect thermistor resistance, an error voltage occurs and is amplified by the bridge amplifier. The error voltage is applied to the top of the bridge and changes the power dissipation of the negative temperature coefficient thermistor. The change of power dissipation causes the resistance to the thermistor to change in the direction required to balance the bridge. Application of RF power to the RF bridge heats the thermistor and lowers its resistance. The bridge circuit responds by reducing the dc voltage applied to the top of the bridge thus maintaining bridge balance.

4-8. If ambient temperature causes changes in the thermistor resistance, the bridge circuits respond by applying an error voltage to the bridges to maintain bridge balance. The voltage at the top of the RF bridge is dependent upon both ambient temperature and the RF input. The voltage at the top of the compensation bridge is dependent upon the ambient temperature only. The power meter reading is brought to zero with no applied RF power by making $V_{COMP}$ equal to $V_{RF}$ so ($V_{COMP}$ - $V_{RF}$) equals zero. Since ambient temperature causes both thermistors to respond similarly, there will be no net difference between the amplifier output voltages. Therefore, any difference in output volrages from the bridges is now due to RF power absorbed by the thermistor mount.

4-9. The RF bridge voltage, $V_{RF}$, and the compensation bridge voltage, $V_{COMP}$, contain the "RF power" information. To provide a meter reading proportional to RF power the dc voltages ($V_{RF}$, $V_{COMP}$) must be further processed by the meter logic circuits.

4-10. The required processing is derived as follows: $P_o$ is absorbed power needed by the RF thermistor to bring its resistance to R ohms (100 or 200 ohms). $P_o$ consists of two components: RF power and dc power supplied by the 432A. The self-balancing action of the bridge circuit automatically adjusts the dc power so that the total power in the thermistor is $P_o$. This dc power is related to the voltage $V_{RF}$ at the top of the bridge by $(V_{RF}/2)^2/R$. Thus

$$\begin{aligned} P_o &= \text{RF power} + \text{DC power} \\ &= \text{RF power} + \frac{V_{RF}^2}{4R} \end{aligned}$$

4-11. RF power can be determined by measuring $V_{RF}$ with and without applied RF power and then doing some arithmetic. But this power measuring scheme is neither convenient nor temperature compensated (since $P_o$ changes with temperature). The 432A introduces another thermistor bridge circuit exposed to the same ambient temperature but not RF power. This circuit includes adjustments (COARSE and FINE ZERO) so that the dc voltage $V_{COMP}$ at the top of its bridge can be set equal to $V_{RF}$. Assuming matched RF and compensation thermistors, $V_{RF0}$ (with no RF power) and $V_{COMP}$ remain equal with ambient temperature fluctuation. They differ only when the RF power to be measured is applied to the RF thermistor. Thus, we have

$$V_{COMP} = V_{RF_0} \text{ when RF power } = 0$$

and

$$P_o = 0 + \frac{V_{COMP}^2}{4R}$$

Combining equations, we have:

$$\frac{V_{COMP}^2}{4R} = \text{RF power} + \frac{V_{RF}^2}{4R}$$

or

$$\text{RF power} = \frac{V_{COMP}^2 - V_{RF}^2}{4R}$$

$$= \frac{1}{4R}\left(V_{COMP} + V_{RF}\right)\left(V_{COMP} - V_{RF}\right)$$

4-12. Thus an RF power measurement reduces to setting $V_{COMP} = V_{RF0}$ (with zero RF power) initially, measuring $V_{COMP}$ and $V_{RF}$, and computing with the above formula. The 432A carries out the computation by forming the indicated sum and difference, performing the multiplication and displaying the result on a meter.

4-13. The meter logic circuits change the two dc voltages to two pulse signals which contain all the RF power information. One of the signals will be a square wave whose amplitude is proportional to $V_{COMP}$ - $V_{RF}$. The other signal will have a pulse width proportional to $V_{COMP} + V_{RF}$.

4-14. The $V_{COMP} - V_{RF}$ signal is obtained by taking the dc voltage outputs from the A1 assembly and applying them to a chopper circuit. This chopper circuit is driven by a 5-kHz multivibrator. The output of the chopper is a square wave signal whose amplitude is proportional to $V_{COMP} - V_{RF}$. The output of the chopper is coupled to the range amplifier and then to the calibration factor amplifier. The amplification that the signal receives in these two amplifiers depends upon the setting of the RANGE switch and the CALIBRATION FACTOR switch. The output of the calibration factor amplifier is V. This current is fed to the electronic switch. A square wave current with amplitude proportional to ($V_{COMP} - V_{RF}$).

4-15. The $V_{COMP} + V_{RF}$ signal is obtained by taking the two dc voltages from A1 assembly through a summing circuit and feeding this voltage to a voltage-to-time converter. The voltage-to-time converter is driven by a 5-kHz multivibrator. The output of the voltage-to-time converter is a signal whose pulse width is proportional to the sum of $V_{COMP} + V_{RF}$. This signal controls the electronic switch. From the $V_{COMP} - V_{RF}$ and $V_{COMP} + V_{RF}$ inputs, the electronic switch provides a 5-kHz pulse train whose amplitude is proportional to $V_{COMP} - V_{RF}$ and whose pulse width is proportional to $V_{COMP} + V_{RF}$. The pulse width is always 90 msec or less.

4-16. The bias circuit switch and filter provides a zero current reference for the meter circuits. This is accomplished by controlling the dc bias to the first stage of the calibration factor amplifier. This circuit, in effect, restores the dc component to the square wave which has been amplified by ac coupled amplifiers.

4-17. The meter is a 0-1 mA, full-scale meter that has a capacitor across its terminals. The capacitor integrates the output pulses from the current switch so the current into the meter is proportional to the time average of the input pulses. That is, the input current to the meter is proportional to the product of

$$\left(V_{COMP} + V_{RF}\right)\left(V_{COMP} - V_{RF}\right)$$

$$= \left(V_{COMP}\right)^2 - \left(V_{RF}\right)^2$$

4-18. The output from the meter is further filtered so the voltage at the rear panel RECORDER output is suitable for use with either a digital voltmeter or X-Y recorder. The RECORDER output voltage is returned to the compensation bridge through the automatic zero circuit when the FINE ZERO switch is depressed. The automatic zero circuit holds a correction voltage at the input of the compensation bridge amplifier, so when the RF is zero, the meter indication will also be zero.

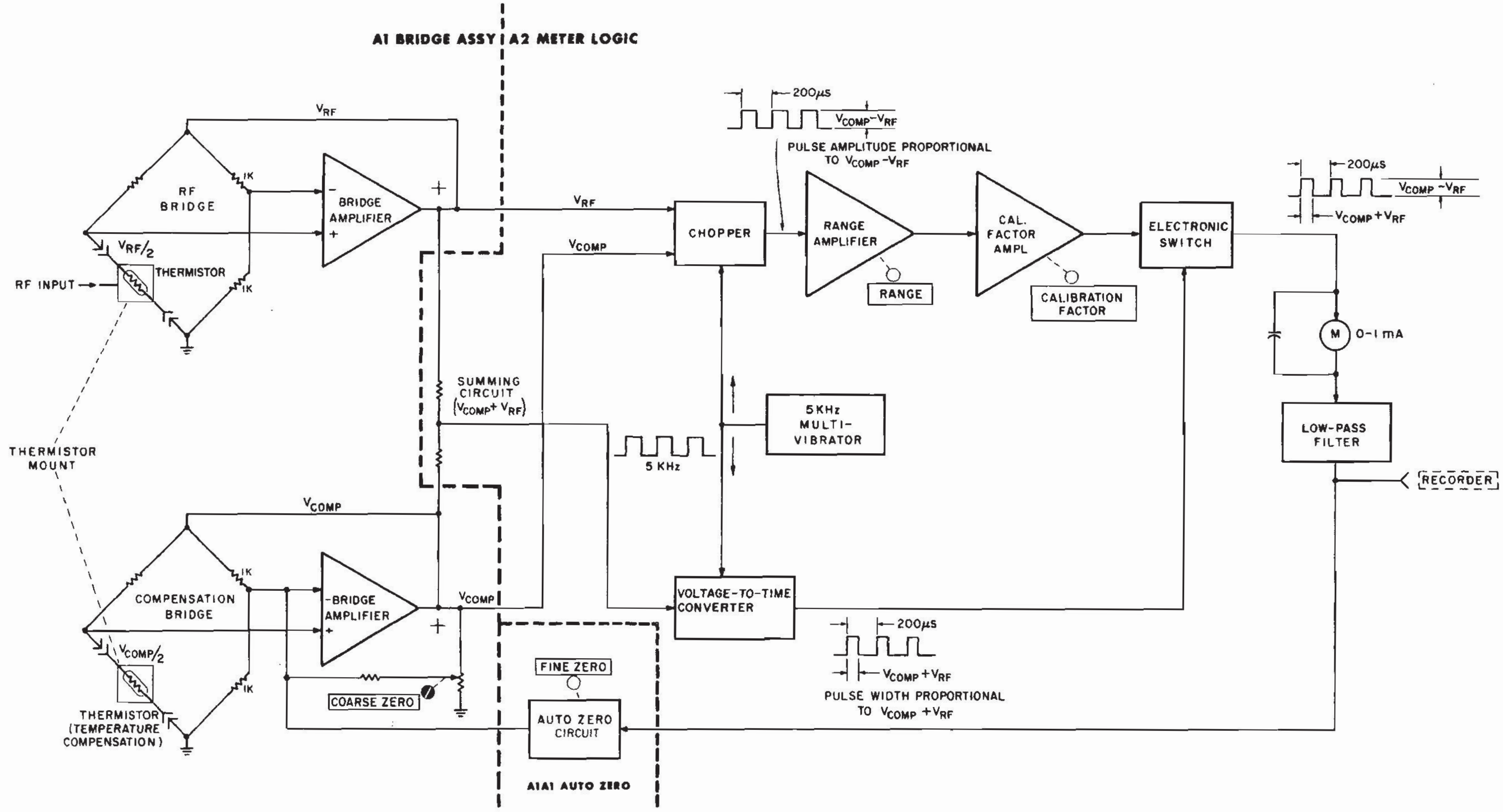

Figure 4-2. Model 432A Block Diagram