



Sandford 'HF' Termination Wattmeter



The Sandford Termination Wattmeter consists of the following three instruments:

1. A dual range (5 & 20 watt Full Scale) Power Meter
2. A 50Ω* Non –Inductive Load (Dummy Antenna)
3. A Resistor pi network giving a -34dB sample output

The wattmeter is intended for use as a piece of test equipment in the QRP enthusiast's shack. The accuracy is better than 10% which compares favourably with commercial units intended for the amateur market. The kit when constructed as per these instructions will dissipate 5 watts indefinitely and up to 20 watts for short periods.

*The actual resistance is $48.4\Omega \pm 5\%$

This kit includes all components and detailed instructions. To complete this kit you will require a soldering iron, solder, small screwdrivers, wire cutters, wire strippers, pliers and (ideally) nut drivers or tube spanners.

Circuit Theory

Figure 1. Shows a simple Termination Wattmeter

The signal from the transmitter is applied to the input coaxial connector and is dissipated as heat in the 50Ω load resistor R_L . If this signal is free of harmonics, a sinusoidal voltage appears at Point A. On positive peaks of this waveform the diode D conducts, charging capacitor C . The voltage at point B drops between peaks as current flows out of the capacitor through the Meter M via its current limiting resistor R_M . This voltage drop is very small because the time constant of the circuit is long compared with the interval between peaks. The diode conducts during time T , and the peak voltage at B is about $0.6V$ lower than the peak at A because this is the forward voltage drop of the diode when it conducts.

Figure 2. Shows the voltage waveforms at A and B.

Figure 3. Shows the complete diagram of the Sanford wattmeter

The 50 ohm load is made of four (4) $50\text{ ohm } 5\text{ watt}$ resistors connected in series-parallel giving a total free-air dissipation of 20 watts . D and C_1 provide rectified DC signal for the meter. R_M and V_{RM} limit the current to the meter and allow calibration. C_2 bypasses the meter for RF energy. The meter is calibrated for 5 watts full scale deflection with the switch in the low position. Connecting the diode to the mid-point of the load provides a second, 20 watt range.

R_L , R_1 and R_2 form a pi network giving an attenuation of 34dB . The addition of the pi network lowers input resistance to 48.4 ohms . When the sample output is terminated in a 50 ohm load, an input of 20 watts results in $8\text{ milliwatts (+9dBm)}$ being dissipated in the sample load. The sample output can be connected to an oscilloscope or a spectrum analyser to monitor the waveform.

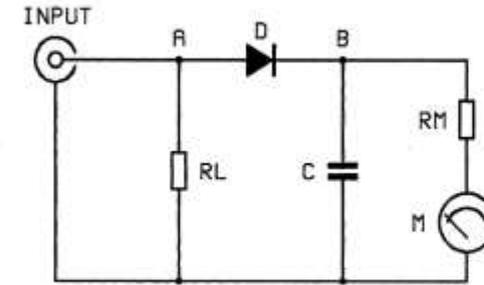


FIGURE 1

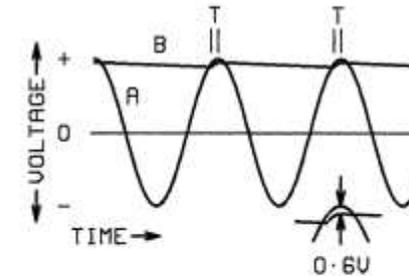


FIGURE 2

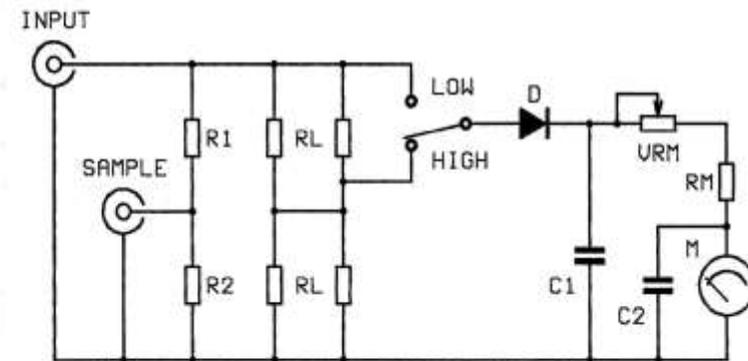


FIGURE 3

Construction Stage 1

The Sanford termination wattmeter is built on a printed circuit board made from fibreglass with a tinned copper tracks on both sides. One side holds the 50 ohm load resistors, the pi network attenuator and the rectifier diode. This is called the “RF side” of the board. The other side holds the capacitors and meter current limiting resistors, and is called the “DC side”. Both sides of the board have an area of copper connected to the case to act as a screen between the RF and DC parts of the circuit.

Insert terminal pins into the three holes as shown in Fig 4. This is the RF side of the board. Use a hot soldering iron to push the heads of the pins until they reach the tinned copper surface of the board then solder them to the copper.

Turn the board over. Take the two smaller solder tags and fit them over the terminal pins as shown in Figure 5. Solder them to the pins and the copper track. Hook a piece of stiff wire through the hole of the solder tags and re-melt the solder while pulling the tag in the direction shown by the arrow. The tag should be in close contact with the surface of the track. Repeat this with the other solder tag. Leave the board to cool.

These two solder tags will be used to hold the board on two of the meters mounting studs. Check the spacing to make sure they fit, re-melting the solder to adjust them if necessary.

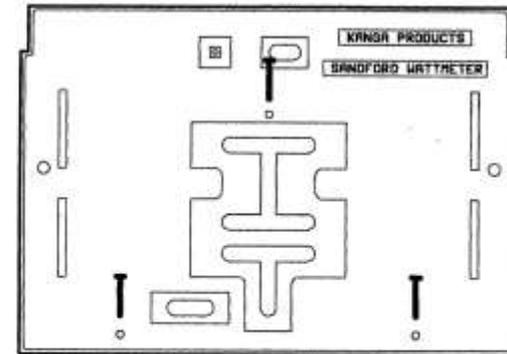


FIGURE 4

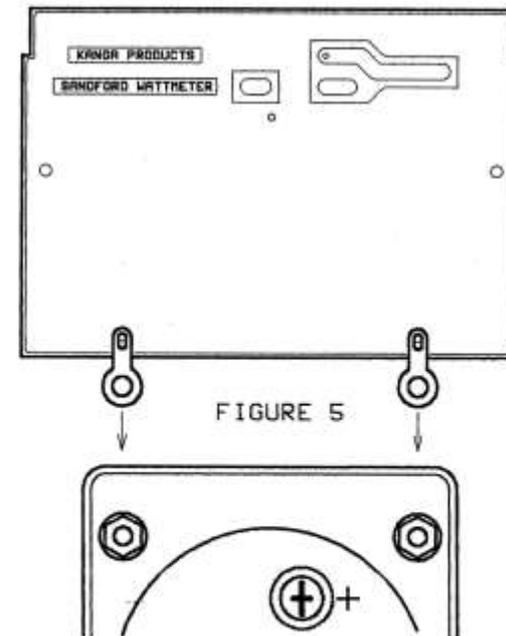


FIGURE 5

Construction Stage 2

Identify the thick film resistors, axial lead resistors and diode from figure 6.

“Be careful and keep heat to a minimum when soldering Components to the PCB thus ensuring component and PCB are not damaged.”

Turn the board over again and locate the four 50 ohm thick film resistors. Solder these to the RF side of the board in the positions shown. The rectangular slot in the copper marks the position of the end of each resistor. This slot should be completely visible See Figure 7.

Bend and trim the leads of the resistors and diode as shown. The lead from the cathode end of the diode, marked with a band, passes through a small hole and is soldered to both sides of the board.

The two axial lead resistors are *“surface mounted”* to the tracks (no holes are provided for them).

Component	Value	Markings
R1	1K5Ω	Brown, Green, Red, Gold
R2	82Ω	Grey, Red, Black, Gold
RL	50Ω	50R J
D		1N4148

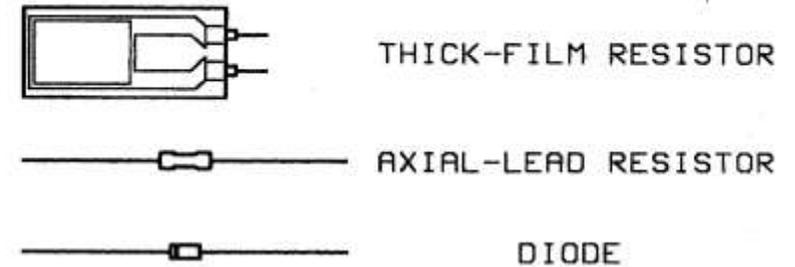


FIGURE 6

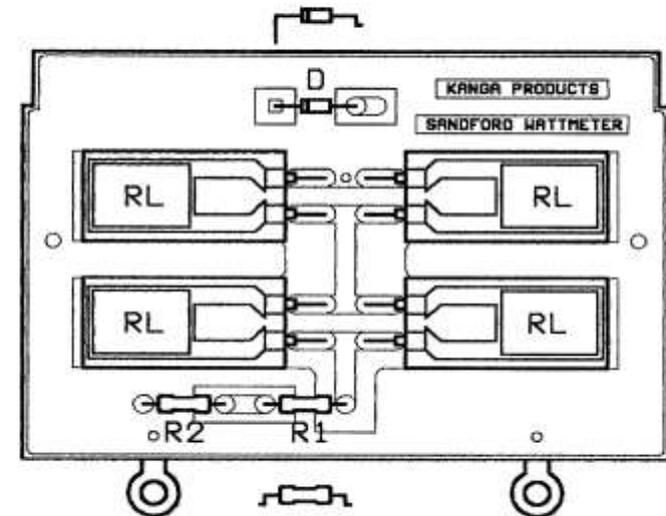


FIGURE 7

Construction Stage 3

Turn the board over again and locate the pre-set potentiometer, the capacitors and the remaining resistor. These components are “surface mounted”. Bend and trim their leads as shown in Figure 8. And solder them to their positions on the DC side of the board.

“Be careful and keep heat to a minimum when soldering the diode to the PCB thus ensuring component and PCB are not damaged.”

The pre-set is used to calibrate the wattmeter. Use a small screwdriver to turn the pre-set control (the central white part of the pre-set) fully anticlockwise for minimum sensitivity.

Component	Value	Markings
C1	10nF	103Z
C2	10nF	103Z
VRM	47K Ω	47K
RM	180K Ω	Brown, Grey, Yellow, Gold

Looking at the edge of the board (Figure 9A) trim off the two lower terminal pins level with the solder joints (Figure 9B). Using pliers, carefully bend the two solder tags at right angles to the board (Figure 9C). Check the spacing against the meter’s mounting studs and adjust the solder tags again if necessary.

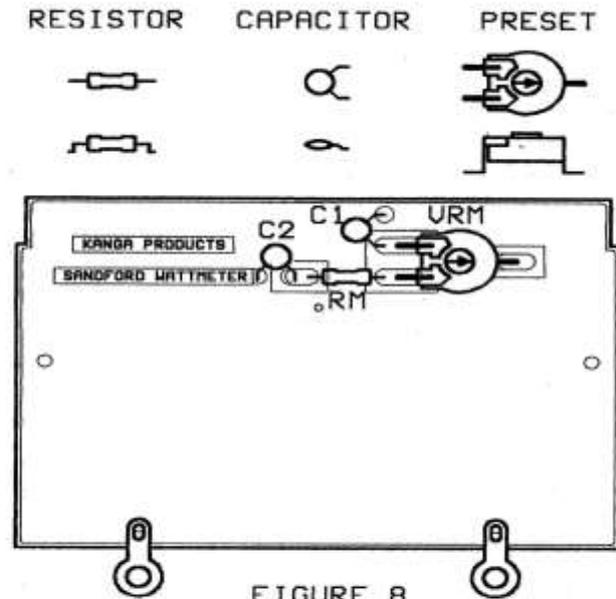


FIGURE 8

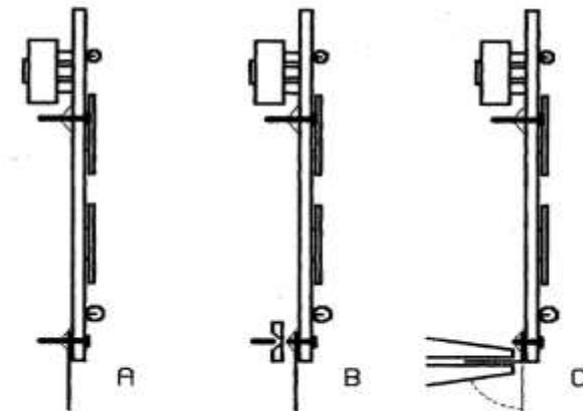


FIGURE 9

Construction Stage 4

The case supplied for your Sanford Wattmeter is has been pre-drilled and screen printed

The original Sanford Wattmeter was designed to give the constructor the choice of Horizontal or Vertical Formats.

Kanga Products will for the time being only produce a kit that is designed for the Horizontal Format, and the box will be screen printed for that style.

Fit the BNC connector, Phono Socket and Switch as shown in Figure 10. Nut drivers or tube spanners are best for tightening the nuts, but pliers can also be used too. When fitting the meter, only fit the two nuts and washers that are furthest from the connectors and switch. The other two will be fitted in stage 5. ***Do not over tighten the meter nuts*** you will damage the meter.

In the following steps, there is a difference between the “horizontal and vertical formats” remember you are following the Horizontal Format. The upper diagram shows the horizontal format.

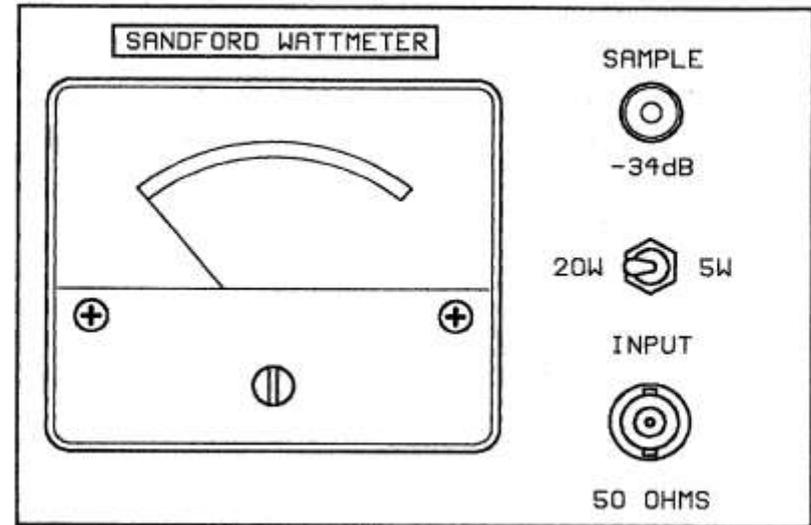
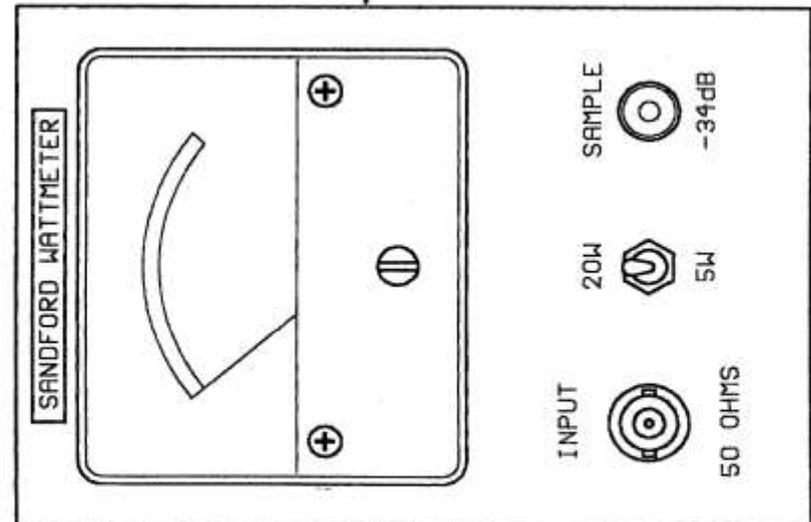


FIGURE 10

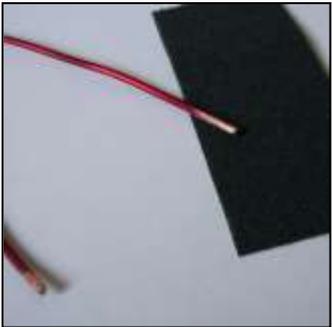
HORIZONTAL FORMAT
VERTICAL FORMAT



Construction Stage 5

Fit the assembled PCB in place by locating the solder tags over the two meter studs and securing them with washers and nuts. Fitting washers and nuts are easier if you follow this procedure. Place the assembly face-down on a soft surface to protect the meter. Rest one end of the thick tinned copper wire on the end of the meter stud. Slide the washer down the wire to guide it onto the stud. Repeat this for the nut. With the wire still in place, use a thin screw driver or other tool to turn the nut until it engages with the tread of the stud. Remove the wire and finish tightening the nut using a nut driver, tube spanner or pliers.

It may be necessary to push the PCB slightly to the left in order to reach the nuts. If so, return the board to its upright position afterwards.



Firstly with the enclosed emery paper remove approximately 3.5 cm (1.5") of the lacquer from both ends of the thick copper wire (see picture) also 2.5cm (1") in the middle. Now using pliers to bend the thick copper wire to the shape shown in Figure 11. Fit the two larger solder tags to the meter terminals using the screws and washers.

Do not over tighten the screws. Fit the ends of the wire through the two holes in the PCB. Solder the wire to the solder tag on the negative terminal of the meter and to both sides of the PCB where it passes through. Trim off the excess wire. This wire acts as an electrical connection and a support for the PCB.

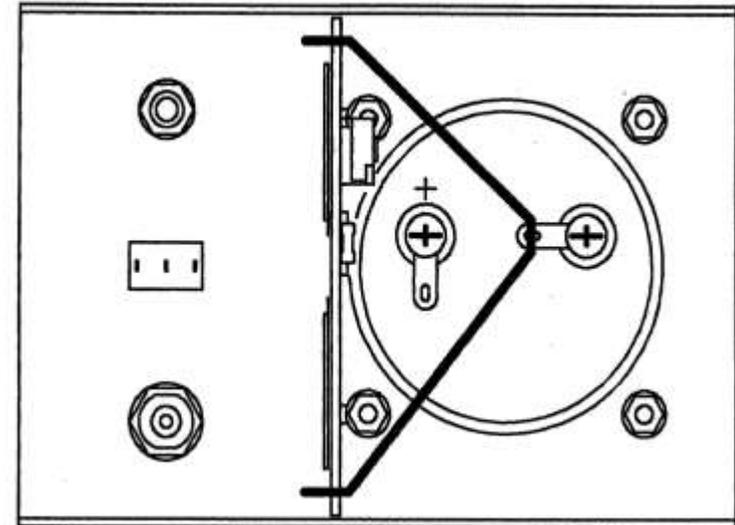
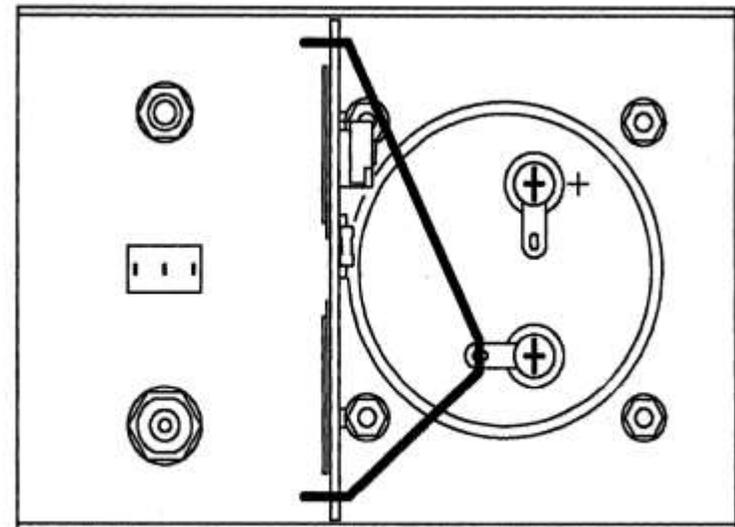


FIGURE 11



Construction Stage 6

Figure 12 shows the inside of the front panel and the RF side of the PCB. These two are now at right angles, so it may help to fold the right-handed side of the page upward along the dotted line.

Use short pieces of coloured insulated wire to make the connections shown

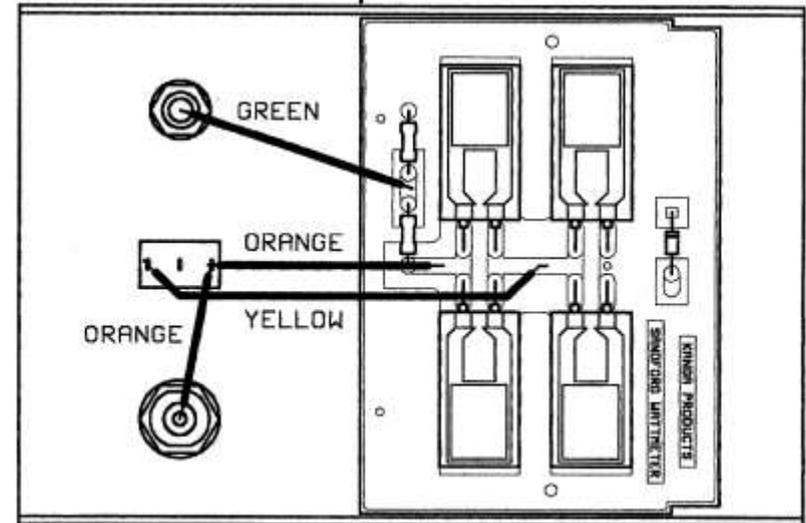


FIGURE 12

Construction Stage 7

Figure 13 shows the inside of the front panel and the DC side of the PCB. These two are now at right angles, so it may help to fold the right-hand side of the page up-ward along the dotted line.

Use a short piece of coloured wire to connect the resistor to the meter positive terminal.

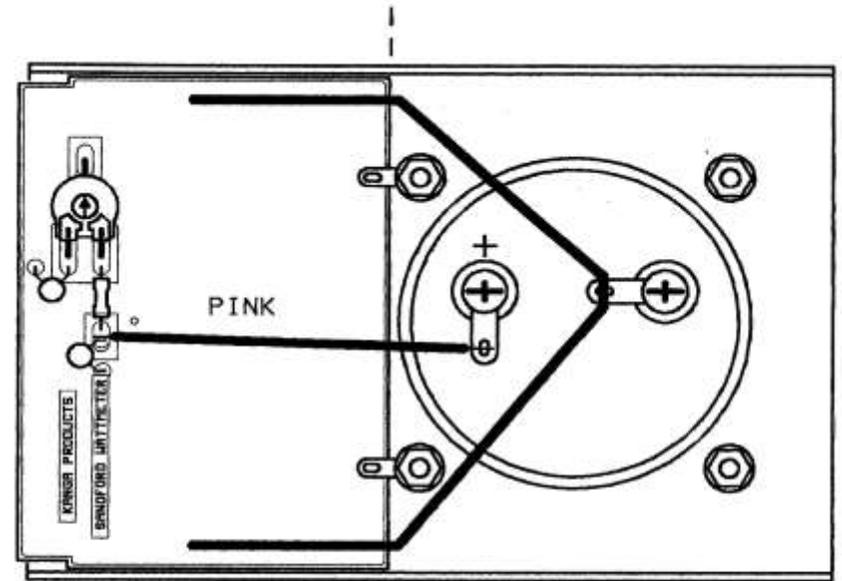
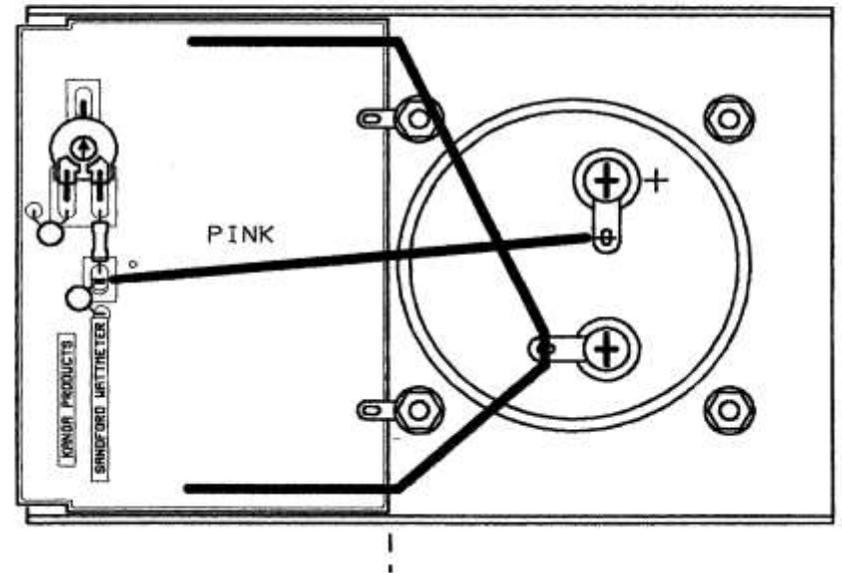


FIGURE 13



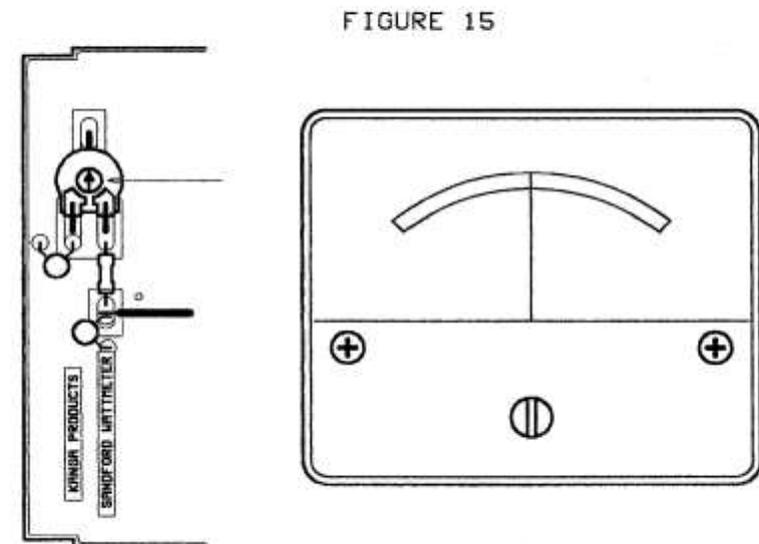
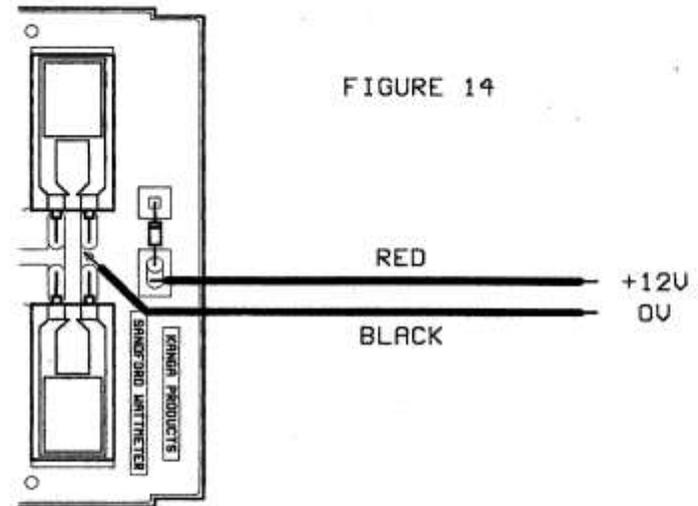
Construction Stage 8

Stand the case up-right that is with the front panel vertical. If necessary, turn the adjustment screw on the meter face until the meter needle is aligned with the left-hand (zero) end of the meter scale.

Using the Red and Black wires connect a regulated 12v DC supply (**Do not use 13.8v**) to the points shown in figure 1. Use a small screwdriver to adjust the pre-set control until the meter needle is aligned with 1.5watts on the lower scale (6 watts on the upper scale) See figure 15. Disconnect the 12v supply and check that the needle returns to zero.

Friction in the meter bearings can prevent the needle returning to zero. This can be overcome by gently tapping the case of the Sanford wattmeter when a reading is being taken. If there is evidence of friction repeat the zero calibration steps above, tapping the instrument gently each stage until the meter needle no longer moves.

Sometimes an electrostatic charge can build up on the plastic face of the meter causing false a reading. If this happens wipe the face of the meter with a soft cloth moistened with a diluted detergent such as washing up liquid. This will prevent the build-up of electrostatic charge.



Construction Stage 9

Disconnect the black wire from the terminal. Connect the red wire between the anode of the diode and the centre contact of the switch as shown in Figure 16.

Fit the back of the aluminium case and secure it with the four screws supplied.

Attach the four Self-adhesive feet to the bottom of the case,

Your Sanford Termination Wattmeter is ready for use.

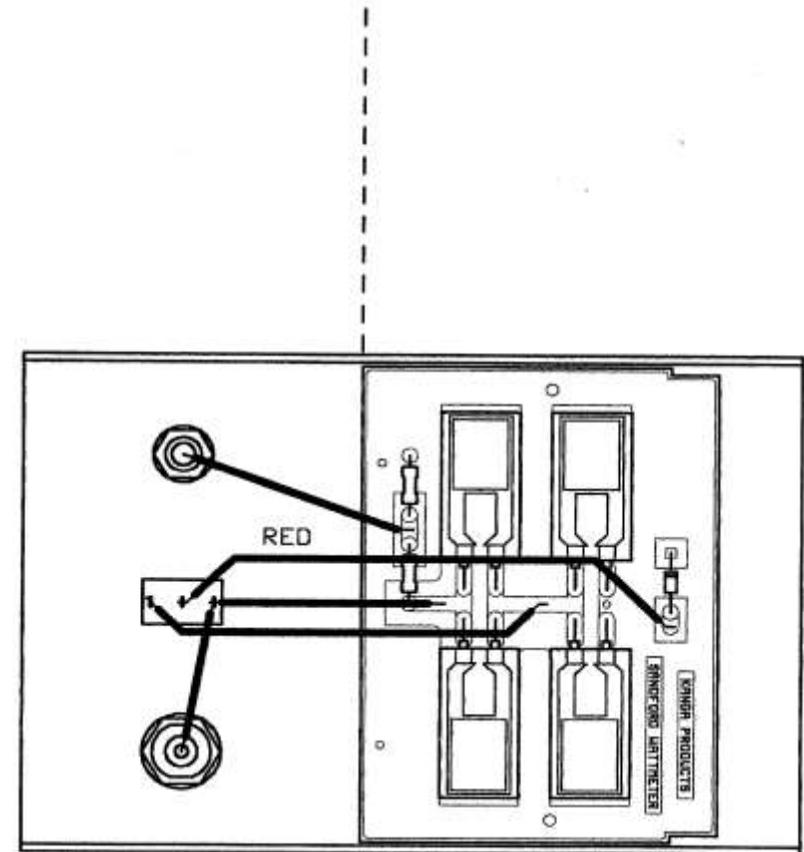


FIGURE 16

Calibration Theory

When a power of 5 watts R.M.S. is dissipated in a 50 ohm load a voltage of 15.81v R.M.S. appears across that load.

$$P \text{ (watts)} = V^2 \text{ (volts)} \div R \text{ (ohms)}$$

$$V^2 = P \times R \text{ and } V = \sqrt{P \times R}$$

$$V = \sqrt{5 \times 50} = \sqrt{250} = 15.81\text{v}$$

For a sine wave, this gives a peak voltage of 22.36v

When a power of 20 watts R.M.S. is dissipated in the same load, the voltage across the load becomes.

$$V = \sqrt{20 \times 50} = \sqrt{1000} = 31.62\text{v}$$

For a sine wave, this gives a peak voltage of 44.72v

The Sanford Wattmeter has a midpoint in its 50 ohm load. Full scale deflection results from an input of 5 watts with the diode switched to the top of the load, 20 watts with the diode switched to the midpoint.

The addition of the pi network reduces the input resistance of the Sanford wattmeter to 48.4 ohms, which is still an acceptable match for the transmitter designed to drive a 50 ohm load. A power of 5 watts dissipated in a 48.4 ohm load results in a peak voltage of 22.00v which is full scale calibration voltage of the meter. An input of 1.5 watts gives a peak voltage of 12.05v. Since 12v is easily obtainable from a variable DC power supply or 78L05/7805 voltage regulator, this makes a convenient calibration point. Using 12v instead of 12.05v introduces an error of only 0.4%.

Using the Sanford Termination Wattmeter

1. *As a Dummy Antenna*

Connect the transmitter to the wattmeter using a coaxial cable to the BNC connector. Do not apply power to the sample output connector. The load resistors in the Sanford wattmeter are rated at 20watts dissipation in free air. In the enclosed space of the wattmeter's case they will over heat if subjected to 20watts of long periods. The wattmeter can safely dissipate 5 watts continually or 20 watts intermittently.

2. *As a Termination Wattmeter*

Connect the transmitter to the wattmeter as described above. Do not apply input power greater than 20 watts. Set the power switch to 20 watt range before applying power. Switch to the 5 watt range only if power indication is below 5 watts.

3. *As an Attenuator*

When power is applied to the input connector and a sample output connector is terminated in a 50 ohm load, a proportion (1/2500th) of the input power is dissipated in that load. An input of 5 watts will result in an output of 2mW (+3dBm) in the sample load. This low-level output can be monitored using a Spectrum Analyser or Oscilloscope. There is no need to terminate the sample load output with a load when the instrument is used as a dummy antenna or termination wattmeter