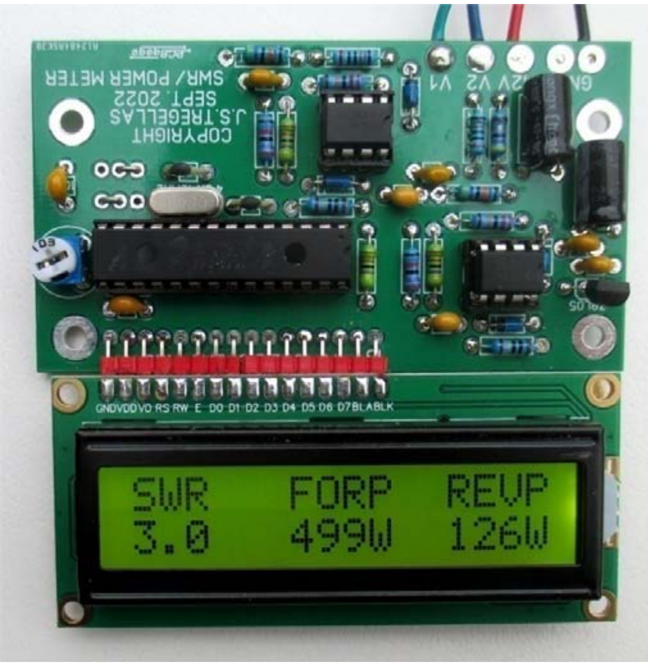
An SWR and PEP Power Meter for HF SSB.

The Microprocessor Supplied in Your Kit

Depending on availability, you may be supplied with one of two types of 16F873 microprocessor. One type runs at 16MHz and uses a 16MHz quartz crystal as a clock generator, while the other type runs at 4MHz and uses a blue ceramic resonator which substitutes directly for the quartz crystal. Both processors are blindingly fast when compared with the rate at which voltage samples are taken from the measurement head, and deliver exactly the same overall performance from the kit.



Introduction

For many years, a cheap and accurate digital HF SWR meter has been a pipe dream of several members of the Adelaide Hills Amateur Radio Society, and this article represents a practical realisation of these thoughts. This instrument reliably displays both SWR and the associated instantaneous forward and reverse powers that produce this SWR figure. It comes in three full scale powers (250, 500 and 1200watts PEP), works from 1.6 to 55 MHz, and accurately displays powers from QRP levels to full scale. It happily shows PEP for both speech, and for continuous test tones from say a two tone test input. It is built around a Tandem Match or Stockton bridge, the operating theory of which was extensively covered in Amateur Radio magazine No.4 2021

How It Works

If the circuit is examined, it will be noted that there are two identical circuit chains which finally feed two A/D converters in the microprocessor (AN0 and AN1 on pins 2 and 3). To keep things simple we will examine the 250 watt version only . Other versions are very similar and only change the scaling resistors R9,R10,R11 and R12 and the number of turns on the toroids. We will examine only one of these chains under conditions of 250 watts applied power to the bridge and an SWR of 1.00. Under this special condition, envelope detector D2 and its associated storage capacitor C3 produce maximum dc output (maximum forward power) while detector D1 and C2 produce no dc output because there is no reflected power.

To give maximum detector linearity, the rf applied to these detectors is made a large as possible so that the effects of the diode forward voltage drop are minimised. With an input to the bridge of 250 watts, the primary current through T1 is 2.236 amps which gives a secondary current of 139.7 ma (turns ratio of 16) which in turn produces 6.98volts rms or 9.88volts peak into D2//C3 and causes R5//R6//R7 to dissipate just under one watt. Similar calculations can be done for the 500 and 1200 watt units.

To ensure that any modulation peak is not flattened by averaging, a short time constant is used between the detector output and IC1a pin 3. This explains why such small values of capacitors are used for C3, C4 ,and C5. The dc output of 9.72 volts from D2 (9. 88 volts minus 0.16 volts of diode drop) is a bit too close to the top end of the input range of the IC1a op amp (with its 12 volt supply) and so it is scaled back to around 7.14volts dc by R9/R11.

Under some measurement conditions, one or both of the detectors receive little rf energy. This situation occurs when the total input power to the bridge is small, or when the SWR is low and little rf is fed to the circuits for reflected power. Under these conditions, these detectors are quite badly non linear due to the forward voltage drops of D2/D1. This non linearity is reasonably well corrected by using the same type of diode (D3/D4) in the negative feedback path of IC1a and IC2a--which are essentially voltage followers with a gain of one .

After further scaling by R15 and R16, the 7.14 volts becomes 4.53 volts dc peak at the input of IC1b (pin 5) which in turn is stored by the sample and hold circuit IC1b in C7. C7 and R19 have a long time constant (1 second) which allows the instrument to store the latest modulation peak while at the same time providing a reasonable recovery time after rf signals cease. Of course, 4.53 volts at either of the two microprocessor A/D inputs (pins 2 and 3) represents a power of 250 watts. Due to the fact that the microprocessor operates from a 5 volt rail, a 250 watt input will consequently not over range the A/D input, where 5 volts represents the maximum input possible to the A/D converter. The stored values of dc voltage in C7 and C8 are then used by the microprocessor to calculate SWR and forward and reverse power.

Building the beast

The fact that the bridge circuit and the microprocessor are built on two different pcbs allows great flexibility in construction. The preferred construction method is to build the bridge circuit into a separate box, creating a test head which can be wired into any desired place in an antenna system. This test head is then remotely connected to the microprocessor and LCD which are placed in a convenient location for viewing. If you pursue this idea of a separate measurement head, then use a two wire screened cable for the interconnection. Of course, both boards can be also built into a single box if desired.

Further flexibility is built in by the way in which the microprocessor board and LCD can be assembled. They can be interconnected as shown in the attached pictures, or with the microprocessor board directly behind the LCD, or with the two boards at right angles. This allows the use of a huge number of enclosures.
Assembly is very straight forward and reference should simply be made to the component overlay drawing. USE IC SOCKETS. If you are going to place the main board directly behind the LCD, use flexible wire or a plug and socket assembly to interconnect the two parts. This will allow access to the back of the main pcb in the event of any errors.

The only area which may give difficulty is the assembly of the toroids and their associated short lengths of coaxial cable in the measurement bridge. Do not try to bring the woven sheath of the coaxial cable out (which forms a Faraday shield). If you do there is a large chance of soldering heat moving back up the sheath wires during assembly and causing shorts because the central insulation has melted. Life is made much easier by inserting a short length of thin tinned copper wire within the woven sheath to make the ground connection for the Faraday shield. The photo shows the various stages in this process. Cut a length of 38mm from a piece of RG58 coaxial cable. Carefully push the central conductor out, and sharpen the insulation at one end to a V point using a knife or bench grinder. Cut the remaining insulation and sheath to a length of 18mm. Reinsert the centre conductor into the external insulation and sheath to reform the flattened woven sheath. Remove the central conductor and insert a short length of thin tinned copper wire within the sheath. Now reinsert the central conductor to form the final assembly and then strip both ends of this back by 3mm.An alternative is to simply place a bare 18mm length of woven sheath over the central coax conductor and ground wire, and then overlay this assembly with heat shrink tube so that the assembly fits snugly and CENTRALLY within the toroid and associated winding.

Finally add the toroid with its 16, 22 or 30 turns of 0.4mm diameter wire to this inner assembly .These turns should be evenly distributed around the toroid circumference. Keep the two ends of the winding at least 1mm apart and cement the ends intp position with a light coat of nail varnish. Tin both wires from the toroid and add the entire assembly to the pcb. Both toroid and coax cable assemblies should be closely identical (particularly with regard to the toroid winding direction) and note that the 16, 22 or 30 turns required on the toroid for the various powers **means that the wire should pass through the centre of the toroid 16, 22 or 30 times**. Before placing the completed sensor pcb into the box, make life easy by soldering 40mm lengths of L shaped bare copper wire to the five input/output points on the pcb, making it ready to connect to the SO239 connectors, ground and two dc outputs on the DIN connector. Last, note the bent over solder lugs shown in the photos which connect the body of both SO239 connectors to the pcb ground plane.
An alternate method of bridge construction is also shown. The plastic box supplied exhibits little rf leakage, but the ultimate construction method is to enclose the sampling head in a diecast box. The printed circuit board supplied can be used, or alternatively, the entire bridge can be constructed in space within the diecast box above a tin plate or un-etched pcb ground plane. This latter method provides much greater safety margins with the large rf voltages involved with the 500 and 1200 watt units.

Setting the unit to work

Provided the toroids have been accurately wound , there is no calibration needed. Measurement accuracy should be better than about 5% over an extended temperature range because that is the worst case tolerance on the 5 volt supply rail to the microprocessor. This rail voltage represents the full scale output count from the 8 bit analog to digital converters of 255 decimal, and hence sets the accuracy of all calculations when an input voltage is compared to it. The only adjustments needed are to set the contrast control for the LCD to produce good visible readings and set the main board jumpers to the wanted power level (250,500 or 1200 watts).. If desired, calibration can be checked by using one of the 50 ohm dummy loads with attached envelope detector detailed on the last page. If a 5% tolerance on power readings is unacceptable, closer tolerance readings may be obtained by changing the value of both R9 and R10 upwards or downwards by say one E6 resistor value .

The PEP power display which the unit produces is interesting. This instrument displays (RMS) power, which is the product of RMS volts and RMS current. For SSB, the display shows PEP which is the (RMS) power of the highest modulation peaks. For a typical 100 watt PEP SSB transceiver set to produce AM, it will typically show 25 watts for an unmodulated carrier, and 100 watts (PEP) for a 100% modulated carrier (unless downward modulation is used). The power quadruples because the voltage doubles at the modulation peaks relative to that of the unmodulated carrier. For FM, the carrier amplitude is constant and so (RMS) power is displayed.

Note that if the assembly displays equal forward and reverse powers and an SWR of greater than 10 with an antenna connected, the coaxial connections to the radio and antenna system are reversed.

Diagnostics

If the assembled unit does not function, first check the obvious things such as the 5 volt supply rail and your soldering (for missed and dry joints, and for solder bridges) . Also check that the chips are in their sockets correctly with no folded under pins. If the LCD displays nothing, check the operation of the microprocessor clock by probing the clock circuit with an oscilloscope and X10 probe. The X10 probe should grasp one lead of a series capacitor of around 4.7pf while the other lead is used to probe the clock circuit. This prevents excessive capacitive loading stopping clock operation. Alternatively, the clock can be checked by listening at 4 or 16MHz with a radio receiver with short wire antenna.

Next, disconnect the bridge pcb from the main pcb. The operation of the bridge can be checked by applying rf to it and noting the dc output that occurs at different power levels by referring to table 4 below .Use the dummy load with rectifying diodes as shown below to measure rf power levels.

Finally check the dc levels through the amplifier chain by directly connecting the on board 5 volt supply to IC1 pin3. The dc levels shown below should be present if all is well .When the same check is done on IC2, the dc voltage levels should be identical but the indicated power will be zero, because the microprocessor software objects violently when the reflected power is greater than the forward power.

Table 1- 5 volts dc applied from output of IC6 to pin 3 of IC1a and IC2a

IC1a/2a Pin3	IC1a/2a Pin2	IC1a /2a Pin 1	IC1b/2b Pin 5	IC1b/2b Pin6	IC1b/2bPin5
5.00V	5.00V	5.16V	3.28V	3.28V	3.39V

Table 2 – 5 volts dc applied from output of IC6 to pin 3 of IC1a and IC2a

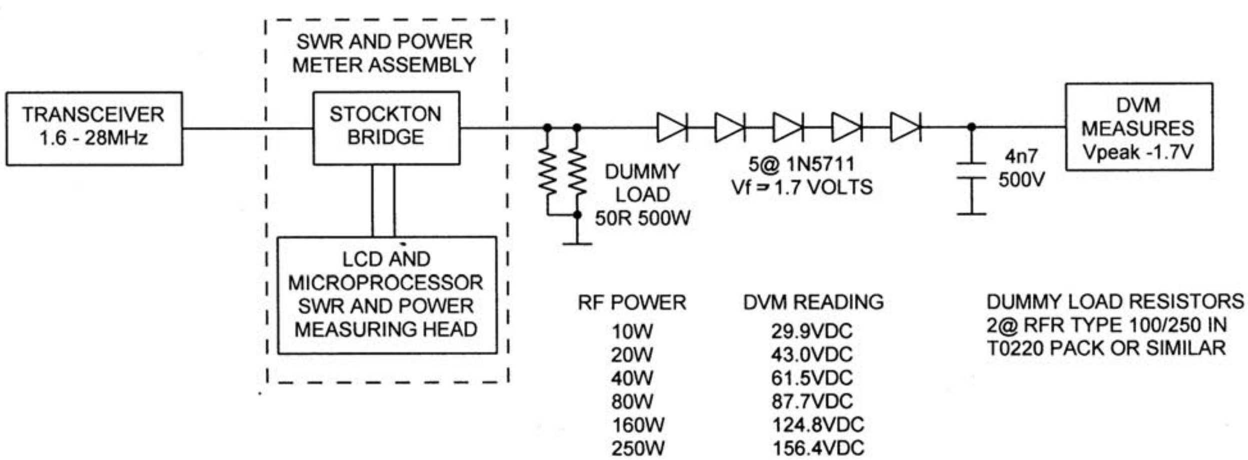
Indicated output power both channels…………… 250 watt unit - 131 watts approx.
500 watt unit- 263 watts approx
1200 watt unit – 633 watts approx.

Table 3 – 5 volts dc applied from output of IC6 to inputs V1 and V2

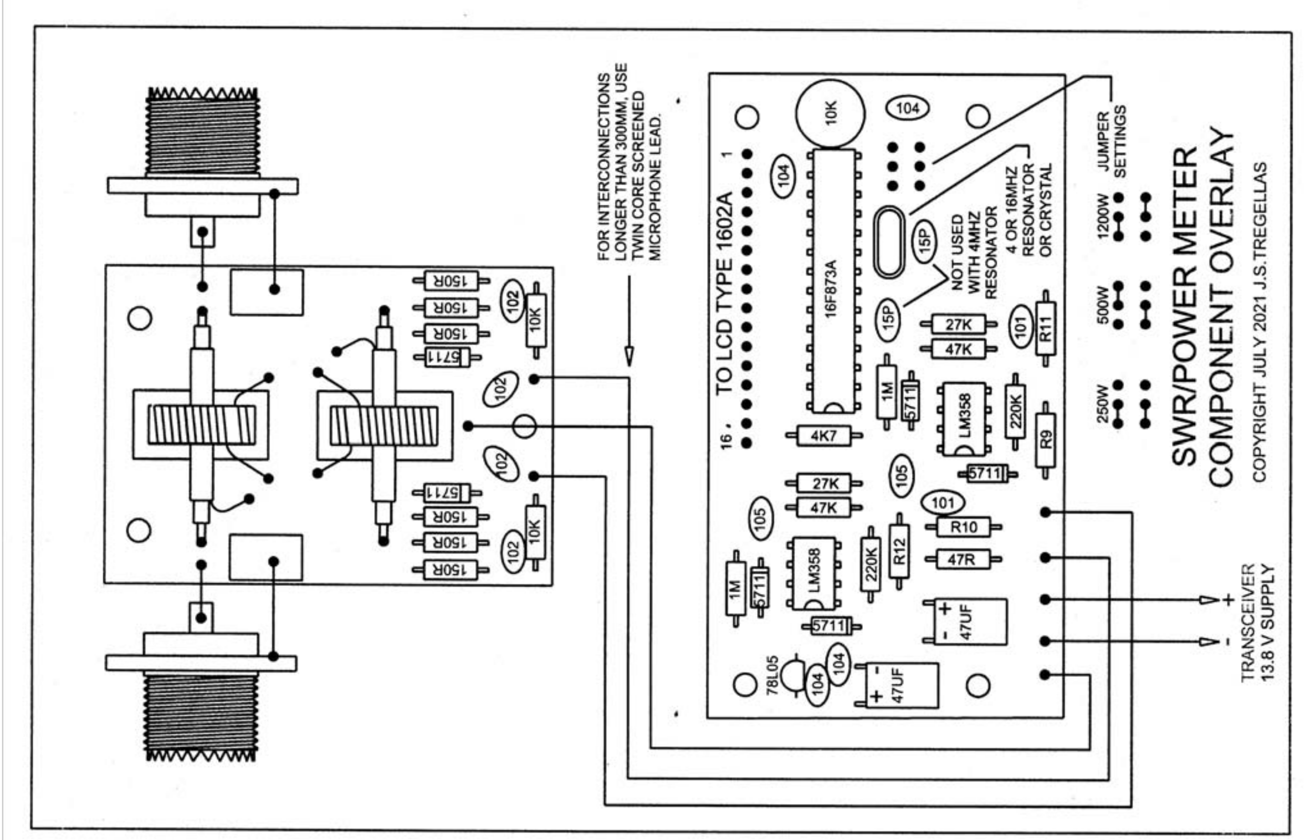
Indicated output power both channels…………… 250 watt unit - 70 watts approx.
500 watt unit- 133 watts approx
1200 watt unit –255 watts approx.

Table 4- Sampling Head DC Outputs

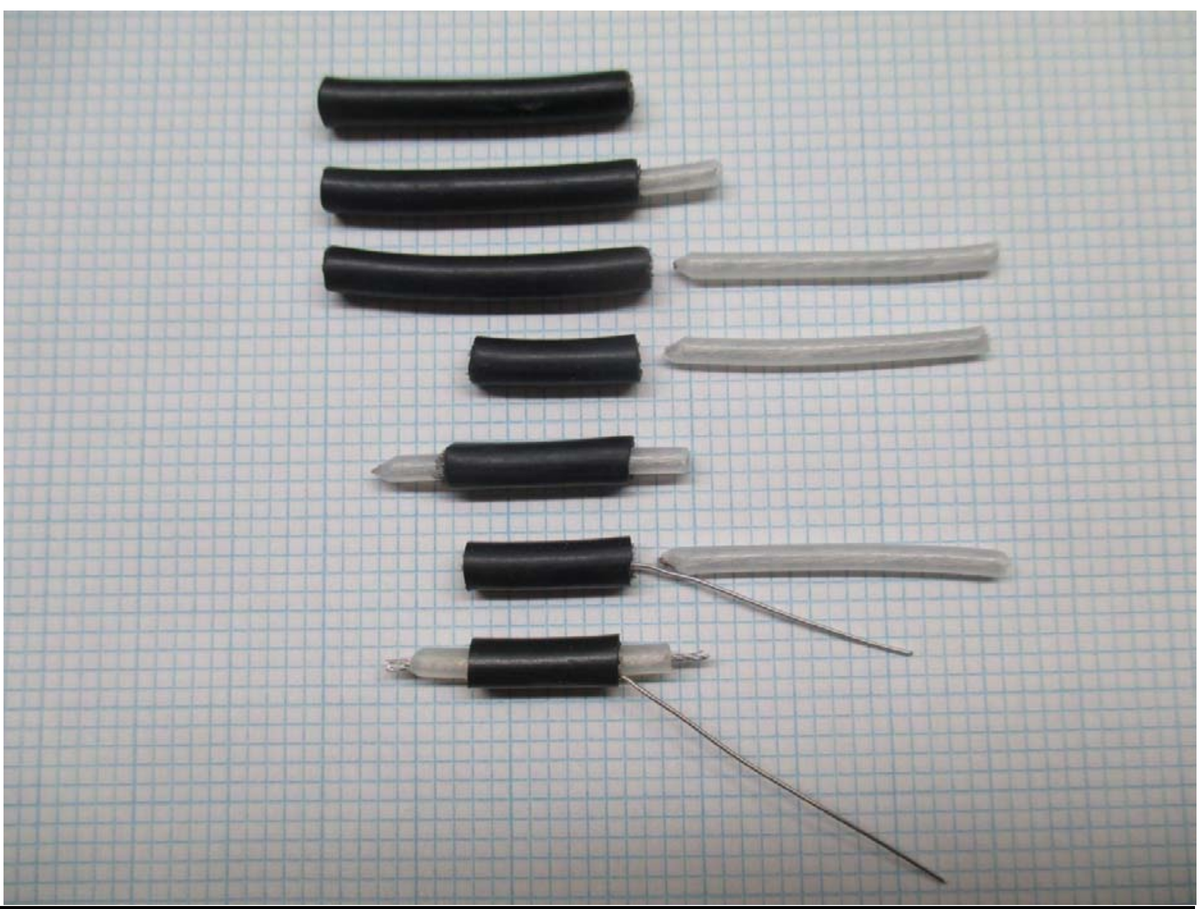
250 watt head…………	50 watts in 4.25volts dc out
	100 watts in 6.09 volts dc out
	250 watts in 9.72 volts dc out
500 watt head…………	100 watts in 4.38 volts dc out
	250 watts in 7.02 volts dc out
	500 watts in 10.0 volts dc out
1200 watt head………..	. 100 watts in 3.23 volts dc out
	250 watts in 5.10 volts dc out
	500 watts in 7.29 volts dc out
	1000 watt in 10.38 volts dc out



TEST RIG TO CHECK RF POWER LEVEL



Preparing Coaxial Cables for Use in the Sensor Head



Master Parts List- SWR and Power Meter

Resistors and trimpots

All resistors are 0.5watt 1% metal film

1@ 47R
6@ 150R
1@ 4K7
2@ 10K
2@ 27K
2@ 47K
2@ 150K
2@ 200K 500 watt only (supplied with all kits)
2@ 220K
2@ 240K 1200 watt only (supplied with all kits)
2@ 390K
2@ 470K 500 watt only (supplied with all kits)
2@ 1M
1@ 5K, 10K or 20K linear trimpot as available

Capacitors

Unless otherwise specified all caps are 50V multiplate monolithic types with 0.2 inch (5mm) lead spacing

2@15pf (used with 16MHz crystal only)
2@ 100pf
4@ 1nF
4@ 100nF
2@ 1uF
2@ 22uF, 47uF or 100uF aluminium electrolytic as available

Semiconductors

1@ 16F873 or 16F873A (software loaded)
2@ LM358 op amps
1@ 78L05 (TO92 pack)
6@ 1N5711 Schottky diodes
1@ 1602A green backlit LCD

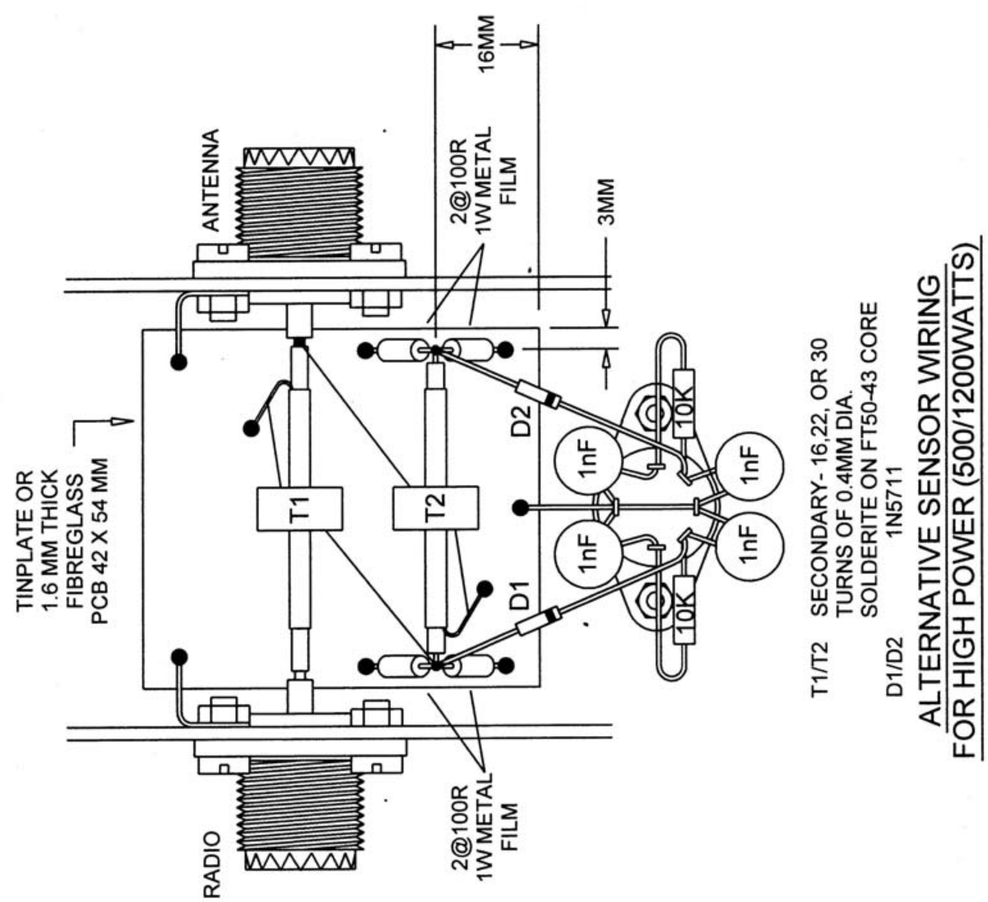
Hardware

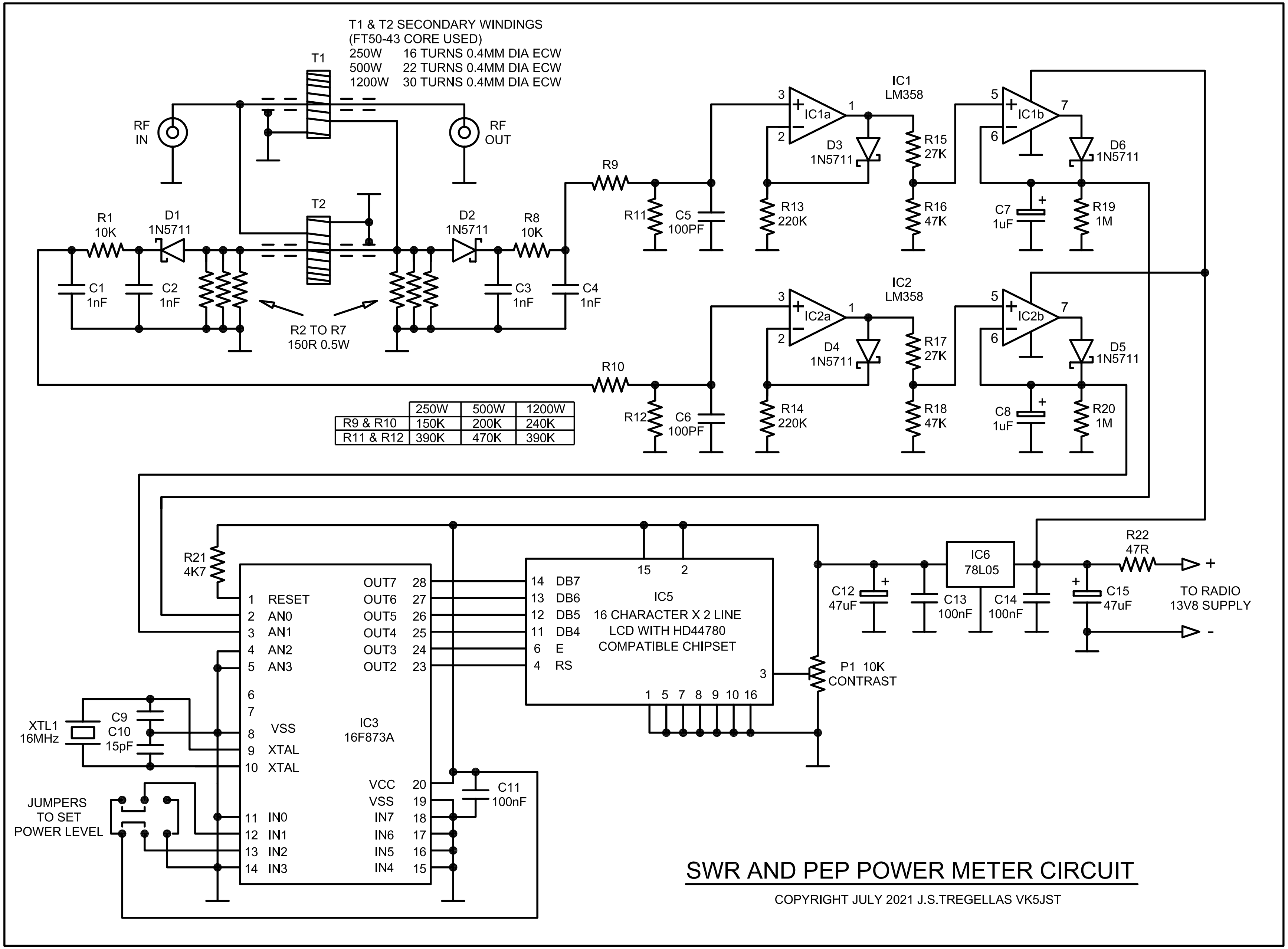
2@ pcbs
1@ 16 pin length of SIL terminal strip
2@ FT50-43 toroids (Fair-rite type 594 3000 301)
1300mm of 0.4mm diameter enamelled copper wire
2@ 45mm lengths of RG58 coaxial cable
100mm of 0.5mm dia. TCW
1@ UB5 jiffy box – Jaycar unit only
10@ M3 pan head Phillips screws 10mm long
10@ M3 nuts
2@ 3.2mm bore solder tag
1@ 4 MHz resonator or 16MHz crystal (depending on microprocessor supplied)
1@ set of assembly instructions

**** Note that it is assumed that the builder will provide the enclosure for the LCD and main pcb

Plugs and Sockets

1@ 28 pin DIP socket
2@ 8 pin DIP sockets
2@ SO239 panel mount sockets
1@ 5 pin panel mount DIN socket
1@ 5 pin DIN plug





	250W	500W	1200W
R9 & R10	150K	200K	240K
R11 & R12	390K	470K	390K

SWR AND PEP POWER METER CIRCUIT