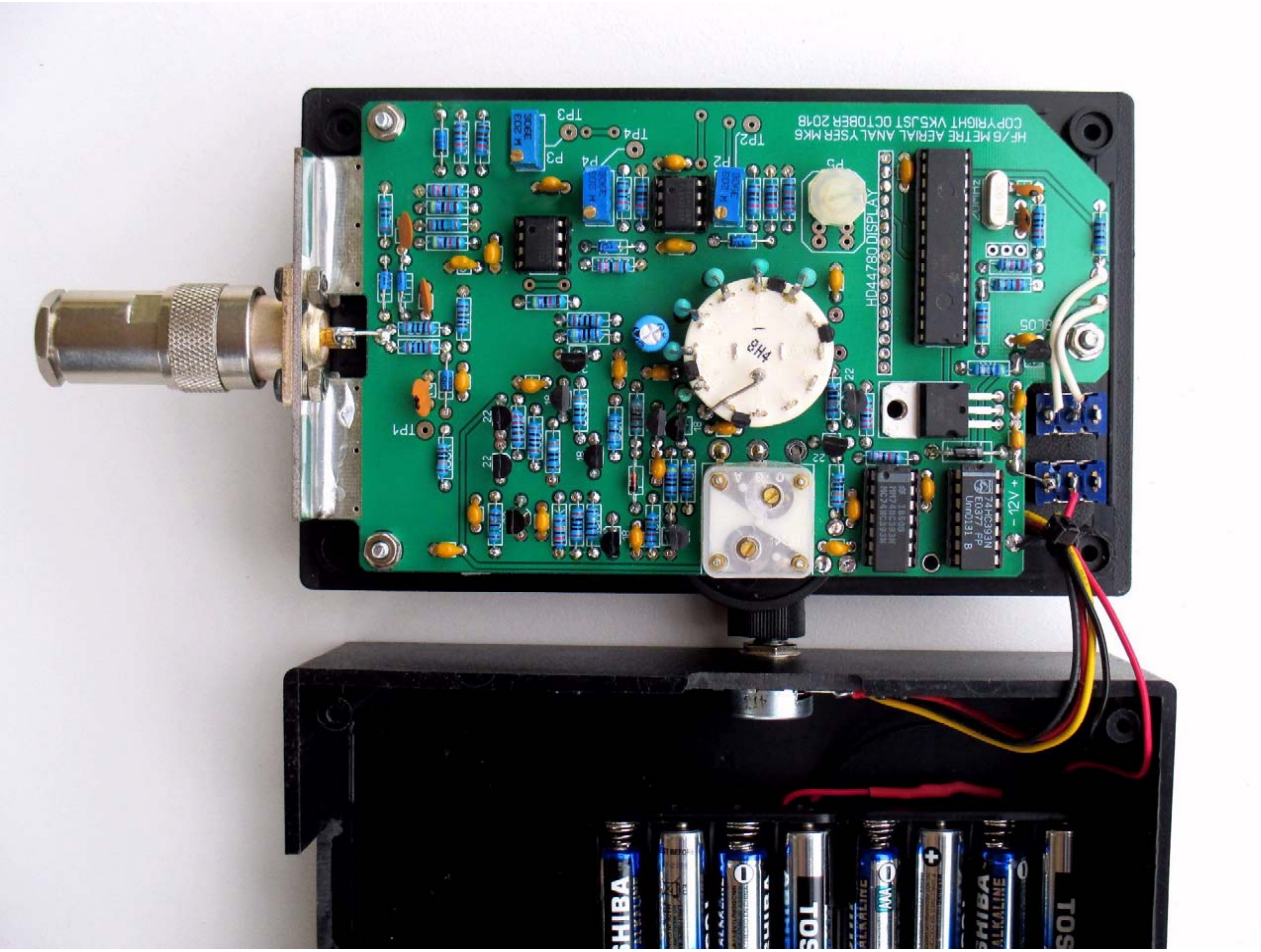

ANTENNA
10.932MHZ R=050Ω
X=000Ω SWR=1.00
24-57MHz
12 – 26MHz
7.0 – 15MHz
4.0 – 8.5MHz
2.3 – 4.6MHz
1.3 – 2.6MHz
ANTENNA ANALYSER
HF & 6 METRES
UPDATE
POWER
SLOW
FAST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HF/6 METRE AERIAL ANALYSER MK6
HD44780 DISPLAY

These instructions represent the minimum data required to assemble the analyser. Much more information is available on my home page http://www.vk5jst.com. Please use it.

The New HF Antenna Analyser- Extended and Easy To Make

Introduction

This article describes a very serious update to the antenna analyser design published back in 2005 in the Australian magazine Amateur Radio. Around 17000 of this exact design were successfully built all over the world, and scratch builders adapted and built many more. The design was bullet proof and if carefully assembled, worked first time, but despite its success, it had what some people saw as two minor problems in an HF analyser. The first of these was the inability to cover 6 metres, although a number of enterprising builders badly overclocked the frequency divider chain to the microprocessor and somehow made it work. The second disadvantage was the pcb which was deliberately designed so that it could be made at home. This was a tremendous advantage for those in third world countries, but made assembly much more difficult.

These inadequacies no longer exist. The new design provides continuous coverage from 1.3 -60MHz, and by adding an optional extra inductor, can also cover the new band at 475KHz. It is built on professionally made plated through hole printed circuit boards and uses no surface mount components. Assembly is dead simple. The output connector is no longer 4mm terminal posts but instead is a high quality 50 ohm N type. A horrible SO239 (or so called UHF) connector can also be used, but this is discouraged as this socket can have an impedance anywhere between 20 and 35 ohms depending on the type of dielelectric used and really does not belong on test equipment. Of course adapters fitted to the N type can provide any type of connector you may want.

The cost is kept down by using a preprogrammed PIC processor, but again if the constructor wants to play about in the control software, this can be directly replaced with a PICAXE 28X2 which is programmed using dear old easily understood BASIC. Note the code for the PIC is proprietary and will not be released into the public domain, while the BASIC code will be freely available. This is to limit the number of cheap unreliable knock offs produced, which in the 13 years since 2005, have caused the author some headaches. The total current drain of the analyser is around 115mA, which has generated complaints from a few users in the past, but is not a lot of current for an instrument which delivers 1 volt rms output into 50 ohms. It compares very favourably with the competition, and even if 900mAH AAA rechargeable batteries are used, gives you around 7-8 hours to walk around your roof and fall off. AA units at 2300 mAH, give a lot more ☺.

Finally, the high level output of 1 volt rms(+13dbm) allows the analyser to keep working in noisy rf environments which cause many other units on the market to fail dismally.

The Basic Theory

As in the previous analyser, the SWR, load resistance, and magnitude of the load reactance are derived mathematically by measuring three rf voltages in a very simple test circuit. First, the voltage across the antenna (or other load) is measured, as is the voltage across a 50 ohm series resistor in the output of the signal generator from which load current is derived. Finally the output voltage of the signal generator is measured. The full mathematics for deriving SWR and the load R and X from these three voltages is up on my website (http://www. users.on.net/~endsodds/analsr.htm) in the subsection Articles and will not be reproduced here to save space.

How It Works

The test network consisting of a 50 ohm resistor(R21//R22) and three envelope detectors (D2 &C16, D3 & C17, and D5 &C18) form the heart of this instrument, and a wide range signal generator provides a constant 1VRMS to drive it via C15 from TR9 and TR10.

The oscillator section of this generator uses a roughly matched pair of transistors (TR3, TR4) in a differential amplifier structure. A parallel tuned circuit in the collector of TR3 (L1-L6, VC1) maximises the gain of this transistor pair at a single frequency and the positive feedback to create oscillation occurs via the emitter follower action of TR4 which couples energy back to TR3 via the coupled emitters of the two transistors. The oscillator output level is raised by a common emitter amplifier TR7 with a gain of 3.9, and an emitter follower TR7 buffers the output of this amplifier stage to provide a high current drive to the output stage TR9/TR10. TR11 and TR10 form a constant current sink of around 43mA, providing an active pull down for TR10 and whatever load is connected to the analyser. This structure produces a class A output stage which provides a very clean sine wave of 1 volt rms to the test circuit. Note that this amplifier has a permanently connected load of 1 Kohm (R20) which provides a dc return path for the 3 envelope detectors.

Fine tuning of the oscillator is accomplished by using the voltage variable collector base capacitance of two back to back PN2222s (TR1 and TR2). This is a very useful feature for measurements on very narrow band antennas such as magnetic loops.

The envelope detector D2 and C16 monitors the level of rf voltage being applied to the test circuit. The dc output of this detector is applied to TR6 via a voltage divider network R11 and R10 and then used to produce ALC for the signal generator. TR5 is hard on at start up due to large base current flow through R8, causing maximum current flow through TR3 and TR4, and hence maximum oscillator gain. As the output level rises, the dc output from D2 and C16, also rises finally turning on TR6 which then reduces oscillator gain by stealing most of the base current for TR5.

All of the dc detector outputs from the test circuit derived from D2, D3 and D5, are highly non linear , due to the large forward voltage drop occurring in each of these three Schottky diodes. This voltage drop creates a seriously non linear relationship between the rf voltage applied to each detector and its dc output, and this must be corrected before the resulting three dc voltages can be applied to the microprocessor A/D inputs and so be used to generate correct calculations. The circuitry following the detectors (IC2 and IC3) linearises these voltages by using the same type of diode in the negative feedback path of each amplifier. Note that the detector comprising D3 and C17 is a floating detector which senses the test circuit current flowing through R21 and R22. The peak value (minus diode drop) of the rf voltage drop across R21// R22 is stored in C17 but unlike the other two detectors , a large amount of rf appears at the junction of D3 and C17. This rf component is removed by heavy low pass filtering (R24,C20) leaving only the dc component at pin 5 of IC2A.

Next are the prescaling circuits which allow the microprocessor to calculate frequency. The sinusoidal output of 2.8 volts peak to peak (1VRMS) is applied to the clock input of a 74HC393 binary counter. IC5 divides by 256 while IC4 divides by 2, giving a total division ratio of 512 and a perfectly symmetrical square wave to drive the microprocessor. The exact 50/50 mark space ratio of this waveform is very important in allowing the microprocessor to count at the highest possible rate.

The microprocessor circuit needs little discussion. The standard microprocessor is the preprogrammed 16F873A which will be supplied with the kit of parts, but a PICAXE 28X2 is directly pin compatible and can be programmed on board through the R39, R40 interface. Of course the PIC processor does not use this port and must be programmed elsewhere. The clock multiplying feature of the Picaxe28X2 requires the crystal to be changed to 16MHz.

Building The Analyser- Mechanical Work

COMPLETE ALL MECHANICAL WORK FIRST. Doing it this way allows you to use the bare main printed circuit board and front panel as templates for all mechanical work the box lid. To do this, place the main pcb EXACTLY centrally on to the rear of the box front panel with the component legend on the pcb facing you (see photo). Use the ridges around the edge of the back of box lid to judge this. When the board has been both horizontally and vertically centralized, clamp it into position and drill the 3 mounting holes using a 3 mm diameter drill. The centre of the hole for the switch shaft should be then be marked out with a sharp scriber using the pcb hole as a guide, and the hole then drilled in two stages- first a 1.5mm pilot hole and then a 7mm drill. If necessary this hole can be opened out later to take account of any errors in drilling. **Note that to prevent dangerous "grabbing" while drilling plastic, the sharp and acute leading edges of all drills should be flattened to zero angle with a diamond stone or fine grinding wheel**. Finally countersink the three 3mm holes on the front of the box lid.

Next the 71x 24.5mm hole for the LCD must be made. Centralise the front panel on the front of the lid and carefully mark this hole out using the LCD hole in the front panel as a guide (see photo). There are a several ways of forming this awkward hole. First is to centrally drill a large hole and then use a nibbling tool. The hole can then be finished off with a medium double cut file. The next method is to cut the hole with a fret or coping saw starting the cut from a central hole. Finally another method (older and harder) is to drill a series of nearly touching smaller holes right around the inside of the marking out. The central piece of plastic is then removed with sharp narrow pointed side cutting pliers, and the hole finished with filing. In all cases file SLOWLY right up to the marking out lines, being particularly careful in the corners and checking the fit of the LCD regularly.

Making the holes in the box bottom is much easier. Mark out the holes for the N connector and tuning capacitor knob with a scriber,square and ruler, and check your marking out against the finished front panel. Then carefully remove almost all the material using the coarse wheel on a bench grinder. Finish off with some fine filing. Alternatively, if you are into pain and suffering, a coping saw and file can be used.

Final Assembly

First, solder the connector printed circuit board to the mainboard. To do this solder two short lengths of copper wire through the connector board. Use these wires to correctly position the connector board relative to the main board (see diagram) and tack the two boards together using minimum solder. Check that the two boards are at right angles and then complete all soldering to form four strong bonds between the two boards. Use at least a 45 watt iron for this.

Next, add all small components to the main pcb using the component overlay and circuit drawings as guides. ASSUME NOTHING!! Use your DVM to check the value of every resistor before installation. Check all capacitor values (150=15pf, 101=100pf, 103=10nF or 0.01uF, 104=100nf or 0.1uF). Depending on who made them, the PN2222 and S9018 come in two different mirror image styles. For this reason the pinouts of your transistors must be checked using the current gain feature on your DVM. An indicated current gain of more than say 40 shows you have the correct pinout.

The lead lengths of all capacitors should be kept as near to zero as possible by installing them with their bodies hard up against the printed circuit board. Do not expect the analyser to work properly if you have used anything other than the multiplate monolithic bypass and coupling capacitors specified, and/or have the capacitors sitting up in the air on the end of 4mm long leads. Leave the installation of all inductors until you install the rotary switch.

Mount all of the trimpots so that the setting screws are oriented as shown on the component overlay. This will allow you to increase each test voltage by rotating the screws in a clockwise direction. When adjusting a 20 turn trimpot, it is very easy to become totally confused and maybe damage the trimpot by overwinding if you do not take this simple precaution.

Do not plug in any ICs yet. Double check the orientation of all diodes and electrolytic capacitors. Leave the mounting of the tuning capacitor and rotary switch until last. Before you mount the tuning capacitor adjust the two trimmer capacitors at the back of the capacitor so that they are totally out of mesh. Attach the tuning capacitor to the COMPONENT side of the main pcb using the supplied screws. Last, mount the rotary switch on the COMPONENT side of the pcb making sure that the common terminal is positioned as shown on the component overlay. Insert all inductors into the pcb in the order shown in the component overlay and complete all wiring between the switch and inductors and the pcb and switch common terminal. Keep your soldering times short and don’t do all the soldering on the switch in one go. Switches exposed to overlong soldering heat have an unhappy habit of going open circuit. Attach the N connector to its pcb with 3mm screws and nuts, and connect the central terminal to the main board using the shortest length of wire possible. Finally solder on all main board flying leads, using 16 @95mm long lengths of various colours for the LCD and 3@130mm lengths for the fine tuning potentiometer. Strip and tin 2mm lengths at either end of the LCD wires before permanently attaching the LCD to the main board.

Assemble the front panel. Attach the front panel to the box lid with thin double sided adhesive tape. Fit the U shaped acrylic spacer supplied with the kit to the LCD on the opposite end of the display to the LED backlighting protusion. Place the LCD in its hole and space it away from the mainboard by using the 50x80mm piece of elephant hide supplied with the kit behind the display. Secure the main board in its final position with 3@16mm long countersunk screws, 3@10mm long nylon spacers and 3@3mm nuts. Attach the main knob to the switch shaft and install the fine tuning potentiometer into the box bottom. Complete all wiring to this potentiometer and to the ON/OFF and UPDATE switches and the battery holders (see photos). Finally attach the battery holders to the bottom of the box, using 2mm thick double sided foam tape.

Testing and Setup

Select the bottom end of the lowest frequency range (around 1.3MHz). Monitor the total current drawn with a DVM (2 amp range). Switch on. The total current should be around 97mA if all is well and the upper line of the LCD should show a row of black squares after the contrast trimpot P5 has been roughly adjusted. Check TP1 with a DVM. About 1.1 to 1.20 volts of dc should appear there and remain nearly constant across all frequency ranges indicating a very flat rf output level. Return to the lowest frequency range. If you have an oscilloscope, the rf output can be checked and should be around 2.8 volts peak to peak (1 volt rms) of good clean sine wave. Switch through all frequency ranges and then go back to the lowest frequency range. Switch off and add all other ICs except the 16F873A microprocessor. Switch on. The total current drawn should now be around 115mA.

Connect a good 50 ohm dummy load DIRECTLY to the output (NO connecting cables to be used). First adjust TP2 to 4.50 volts using P2, and then adjust TP3 to 2.10 volts and TP4 to 2.15 volts using P3 and P4. Switch off and add the preprogrammed 16F873A microprocessor. Switch on. At startup, after the contrast trimpot P2 is further adjusted to give the best display, the LCD should indicate the actual battery voltage within 5%. (Ifdesired, this can be later adjusted to the exact value by playing with R42 and R43). A few seconds later, the LCD will indicate the frequency, load resistance (50 ohms), magnitude of load reactance (zero ohms) and SWR (1.00). Now switch through all the frequency ranges and check that the SWR remains under 1.05 and the indicated resistance stays within the range 48-52 ohms. The reactance X should remain at zero. If all is well, go back to the lowest frequency range and load the output with a 0.25W 150 ohm metal film resistor. A resistance of 150 ohms +/- 10% should be indicated with X=0. Also check using a 10 ohm resistor. Please note that the exact test point voltages required to produce the above results depend to a small degree on how well the resistance of the dummy load matches that of the internal 50 ohm current sensing resistor (R21//R22) and the relative matching of the diodes in the three envelope detectors. Bluntly, you may have to play around very slightly with P3 and P4 to get the very best compromise over the total frequency range. In no case should the voltages at TP3 and TP4 fall outside the limits 2.05 and 2.20 volts with the 50 ohm load ON THE LOWEST FREQUENCY RANGE while this optimizing is being done. Note that the setup procedure forces the microprocessor to calculate and display a load resistance of 50 ohms, cancelling all tolerances in both the internal 50 ohms and dummy load.

The Optional Z Meter

A great addition to this analyser is an analog Z meter which displays the MAGNITUDE of the load impedance.i.e. the magnitude of the vector sum of the load R and X. This is very useful because (a) the reading is instantaneous and (b) when the indication has been reduced by careful tuning to a minimum, the meter actually indicates the resistive component of the load i.e. in the case of an antenna, the radiation resistance which the matching network must drive. For a transmission line, it will very accurately indicate the voltage minimum associated with exact quarter and half wave lengths of the line when the other end of the line is either open (odd multiples of quarter wave) or shorted (all multiples of a half wave). Add a coil of a few turns to the analyser output, and you can use it like a dip meter, doing things like accurately measuring the resonant frequency of antenna traps etc. As this meter must indicate the voltage appearing across the load, it is connected between TP4 and ground.

After the previously specified initial adjustments have been done with the 50 ohm load, **with no load connected and on the lowest frequency range**, around 4.2 volts dc should also appear at TP4. This voltage is used to set full scale on the meter, representing an open circuit load. If a 50 ohm load is now connected, the load voltage halves (due to the 50 ohm output impedance of the analyser) and so a load of 50 ohms is represented by one half of full scale deflection on the meter face.

There are two ways of adding this meter. The simplest is to just take connections from TP4 and ground to plugs on the outside of the box to which a standard analog meter can be connected. Alternatively, if the analyser is built into a larger box, then a small standard moving coil meter can be permanently wired into circuit. Any meter with a full scale deflection current of up to 1 mA can be used and the meter series resistor is selected to provide full scale deflection when around 4.2 volts dc is applied to the combination. A meter scale can be downloaded from my website.

Note that the meter will not indicate full scale at the higher frequencies, because a short length of 50 ohm transmission line is permanently connected to the measurement circuit at the analyser output. This, of course , is the N connector which has a capacitance of around 4pF giving a reactance of around 600 ohms at 60 MHz. This is why ALL adjustments on the analyser must be done at the bottom end of the lowest frequency range forcing this capacitance to exhibit a very high reactance which can be ignored! This short length of 50 ohm line (about 30mm through the connector) is added to the 50 ohm line length connecting the analyser to the load and in most measurements can be ignored (only 0.5% of a wavelength at 6 metres).

Final Comments

Congratulations ! You now have a piece of test gear which can make measurements on antennas, transmission lines, baluns, ununs, stub matching systems, and other odd things like the optimisation of antenna traps and the output networks of linear amplifiers. Add the use of Smith charts to your capabilities and you are well on your way to becoming an antenna guru.Enjoy! ☺.

VK5JST November 2018

Parts List – 60MHz Analyser Using PN2222 and S9018 Transistors

Resistors – all 0.25 watt 5% metal film

1@10R	1@15R	1@68R	5@100R	2@390R	3@470R
1@1K	1@2K2	2@4K7	7@8K2	1@10K	1@15K
3@22K	1@33K	3@47K	1@82K	3@100K	1@120K
3@220K	2@10M				

Capacitors

2@15pF NPO
3@100pF NPO
3@10nF (0,01uF) 25V monolithic
19@100nF (0.1uF) 25v monolithic
1@1uF 25V monolithic
1@22uF 16V aluminium electrolytic
1@160pF variable capacitor (Jaycar Pt. No. RV5728) –also called polyvaricon

Semiconductors

7@PN2222	4@S9018	
1@1N4148	6@1N5711	1@1N4004
1@78L05	1@LM317L	1@7808
2@TLC27L2		

2@74HC393   1@16F873A with preloaded code
1@1602 16 character x 2 line backlit display with HD44780 (or equivalent) encoder

Inductors -all rf chokes

1@270nH	1@1uH	1@3.3uH	1@10uH	1@33uH	1@100uH

Switches

2@ single pole double throw subminiature switches- C&K type 7101 or equivalent
1@ single pole 12 position rotary switch (Jaycar SR1210/ Altronics S3012 or equivalent)

Potentiometers

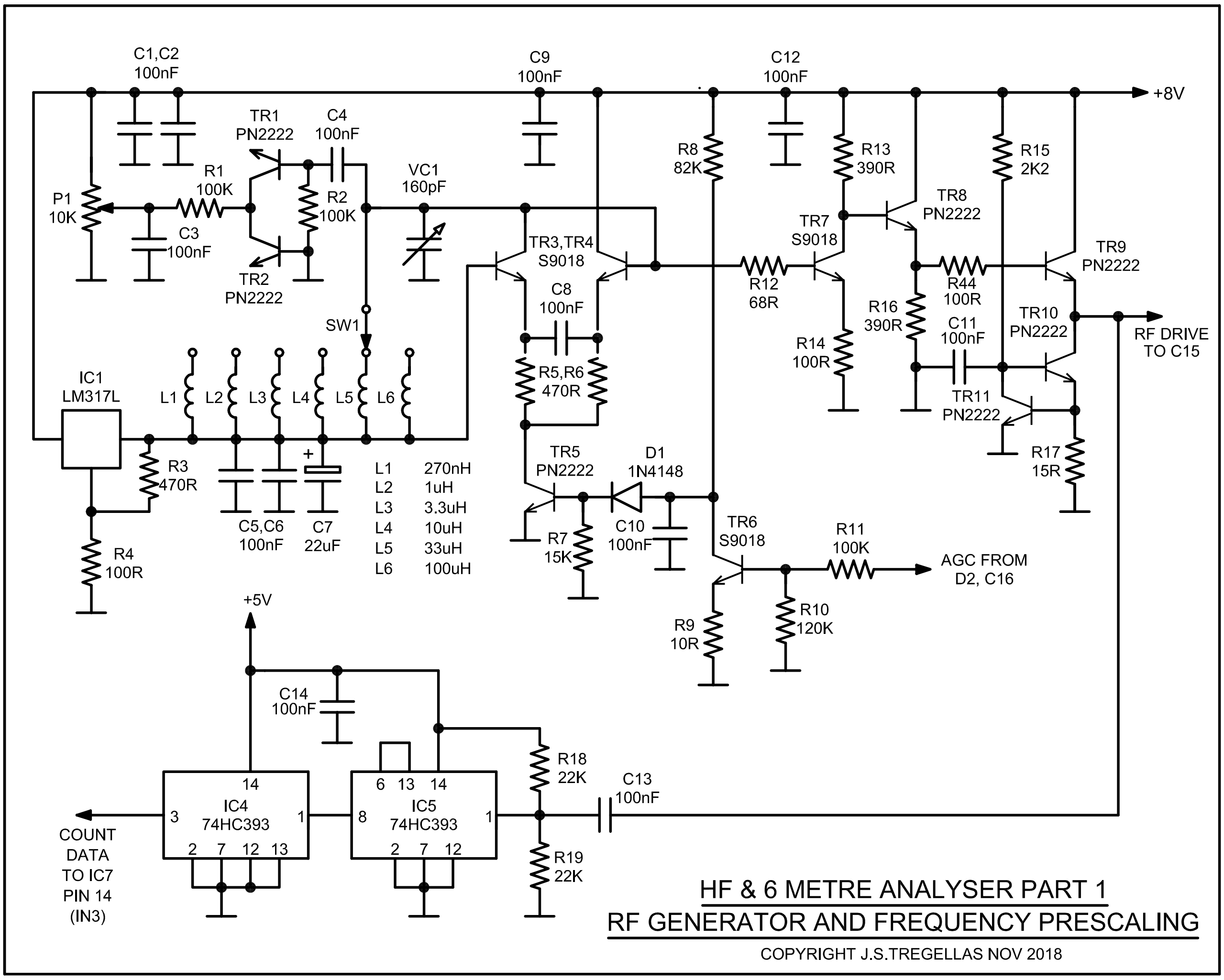
1@10K linear 16mm diameter potentiometer (Altronics R2225) with nut and washer or equivalent
3@20K linear 25 turn cermet trimpots (Jaycar RT4652) or equivalent
1@ 10K linear pcb mounting trimpot (Jaycar RT4360) or equivalent)

IC Sockets

2@ 8 pin DIL
4@14pin DIL- use 2 sockets in line for the 28 pin 16F873A

Miscellaneous

3@ 3mm x 16mm long countersunk screws
4@ 3mm x 6mm long cheesehead screws
7@ 3mm nuts
3@ 3mm bore 10mm long nylon spacers
1@ knob for rotary switch
1@ knob for fine frequency adjusting potentiometer
1@ acrylic spacer for 1602 HD44780 display
1@ foam spacer for 1602 HD44780 display
1@ 20MHz crystal
1@ panel mounting N connector Part No. N01-FJHL4-41BS00
1@ UB1 Jiffy box –black- Jaycar Pt.No. HB-6011 or Altronics H0201
2@ AAA 4 cell battery holders
1@ PCB set- main, connector, and front panel boards
1@ set of assembly instructions
1@ mailing envelope
Various colours of plastic covered hook up wire


C1,C2
100nF
C9
100nF
C12
100nF
+8V
TR1
PN2222
C4
100nF
VC1
160pF
R1
100K
R2
100K
P1
10K
C3
100nF
TR2
PN2222
TR3,TR4
S9018
C8
100nF
R5,R6
470R
R8
82K
R13
390R
TR8
PN2222
R15
2K2
TR7
S9018
R12
68R
R14
100R
R16
390R
R44
100R
C11
100nF
TR9
PN2222
TR10
PN2222
RF DRIVE
TO C15
TR11
PN2222
R17
15R
SW1
IC1
LM317L
L1
L2
L3
L4
L5
L6
R3
470R
C5,C6
100nF
C7
22uF
L1 270nH
L2 1uH
L3 3.3uH
L4 10uH
L5 33uH
L6 100uH
R4
100R
TR5
PN2222
D1
1N4148
R7
15K
C10
100nF
TR6
S9018
R11
100K
AGC FROM
D2, C16
R9
10R
R10
120K
+5V
C14
100nF
R18
22K
C13
100nF
R19
22K
IC4
74HC393
IC5
74HC393
14
3
1
2 7 12 13
6 13 14
8
1
2 7 12
COUNT
DATA
TO IC7
PIN 14
(IN3)
HF & 6 METRE ANALYSER PART 1
RF GENERATOR AND FREQUENCY PRESCALING
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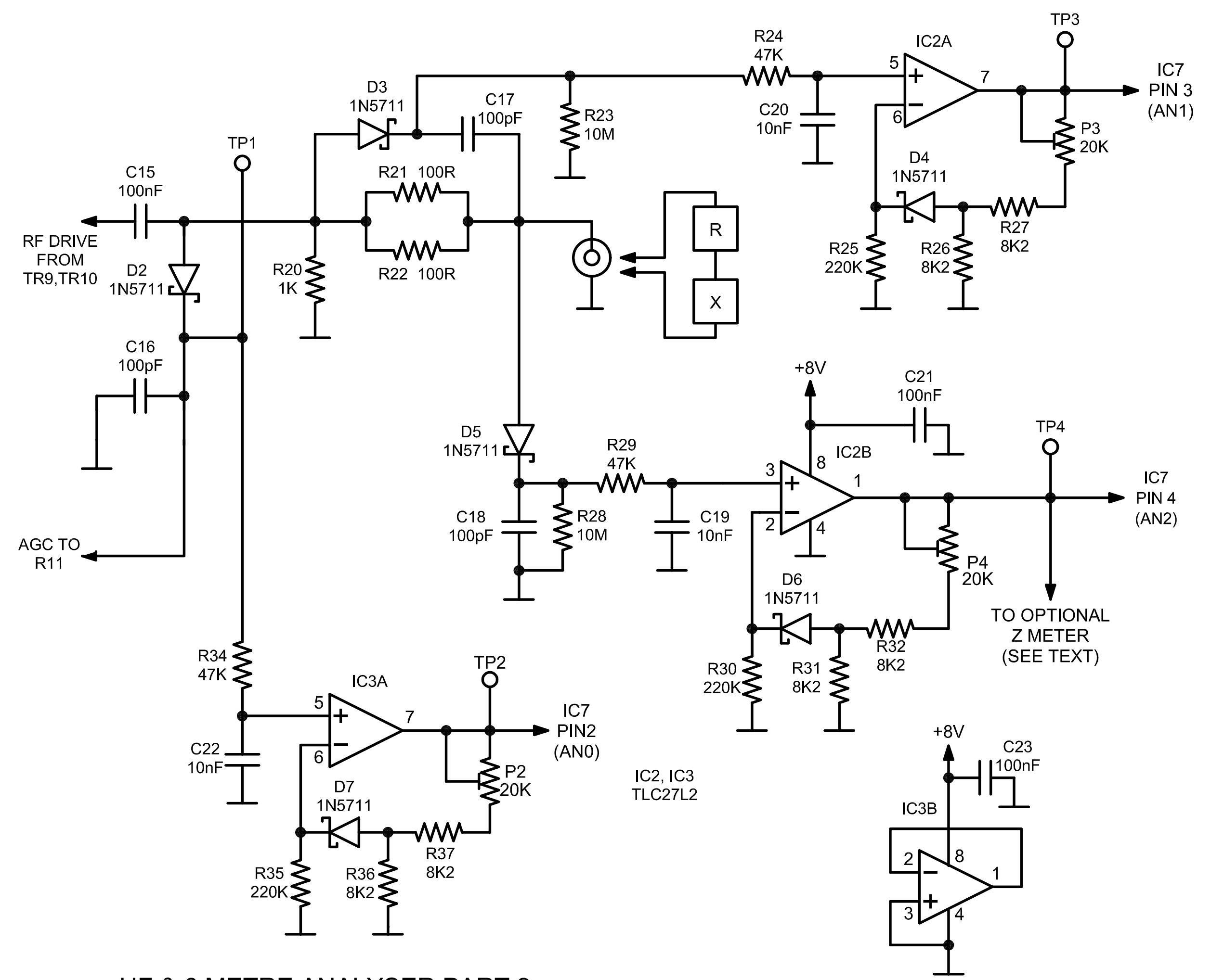
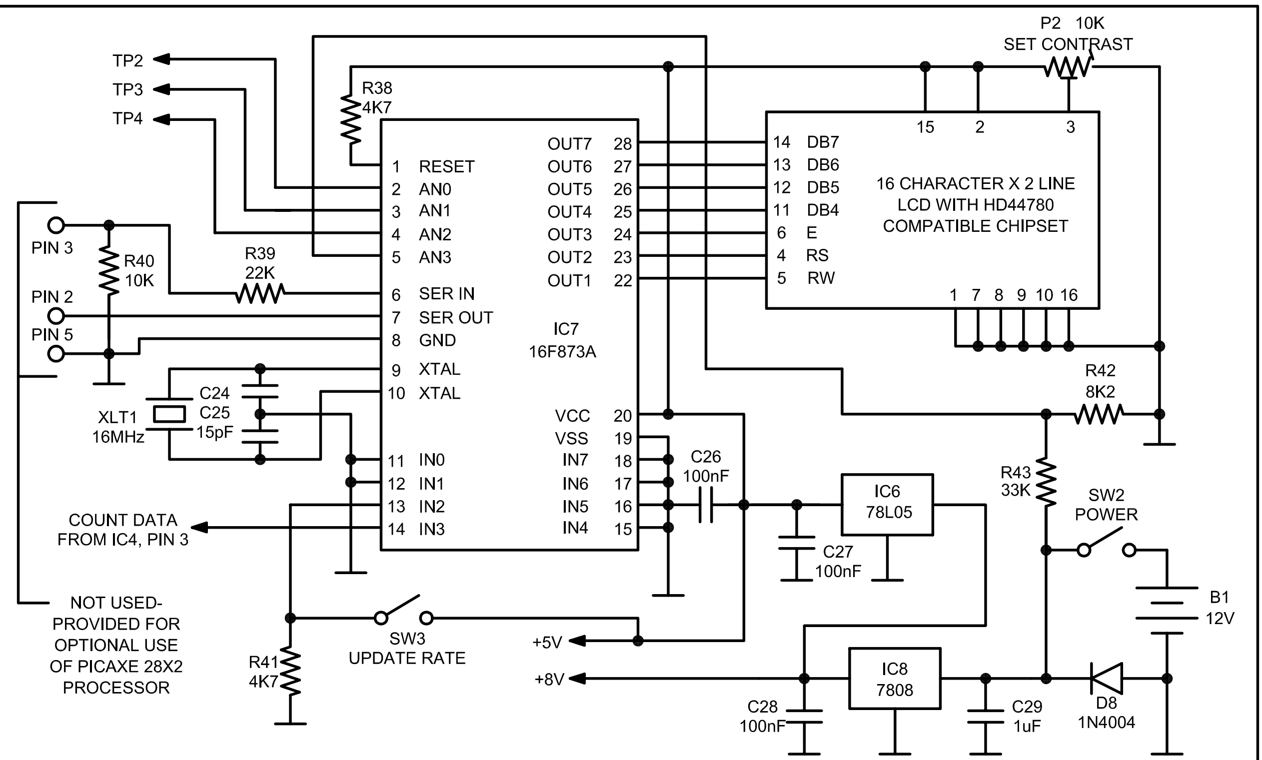
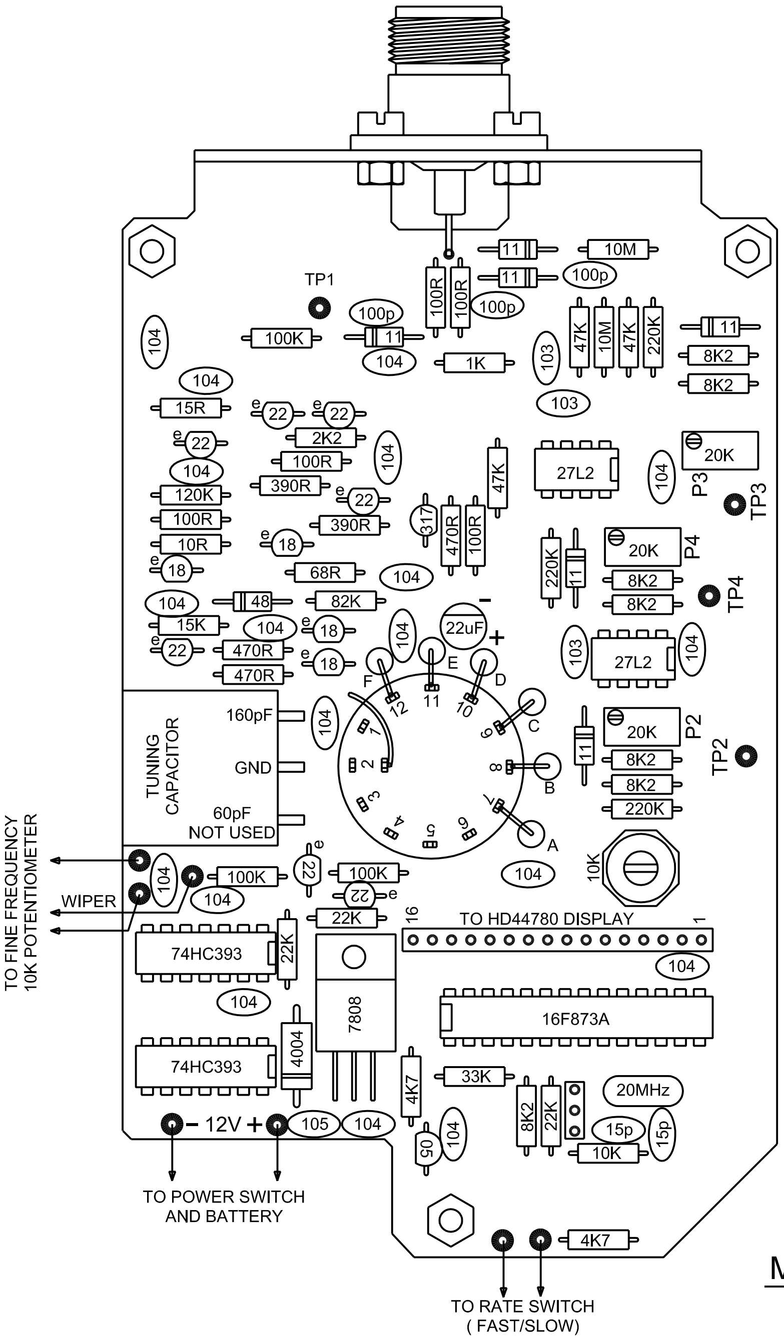


HF & 6 METRE ANALYSER PART 2
TEST CIRCUIT, DETECTORS, AND LINEARISATION

NOTE....R33 DELETED 30/3/19



HF & 6 METRE ANALYSER PART 3
MICROPROCESSOR CONTROL, DISPLAY, AND POWER SUPPLY

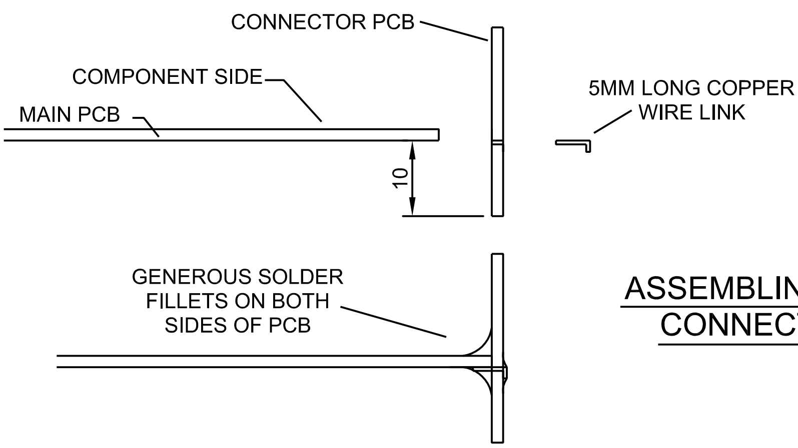


COMPONENT LEGEND

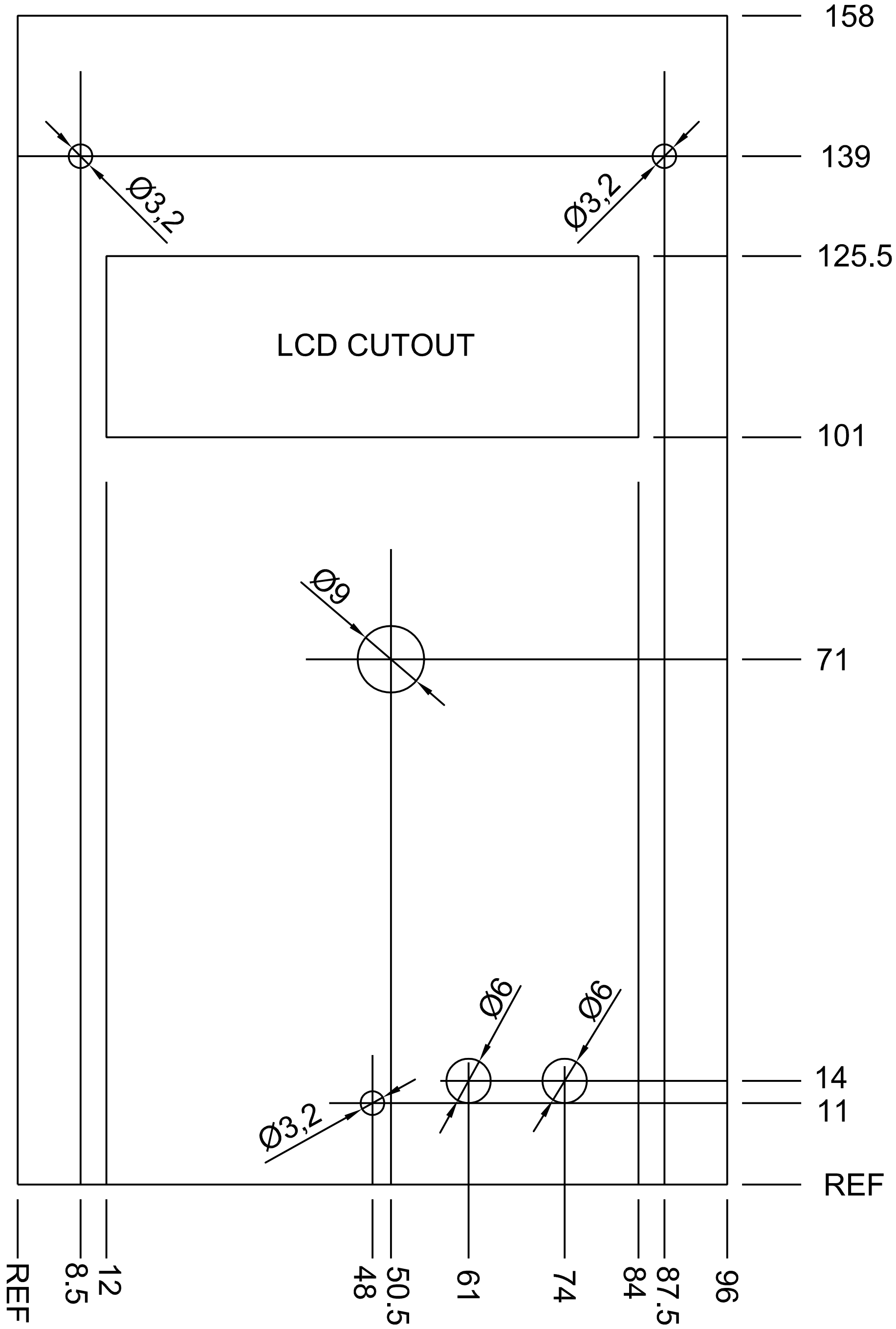
05	78L05
317	LM317L
18	S9018,SS9018
22	PN2222, 2N2222
48	1N4148
11	1N5711
4004	1N4004
15P	15pF NPO
100p	100pF NPO
103	10nF MONOLITHIC
104	100nF MONOLITHIC
105	1uF MOMOLITHIC
22uF	22uF 16 VOLT ELECTRO.

A	100uH
B	33uH
C	10uH
D	3.3uH
E	1uH
F	270nH

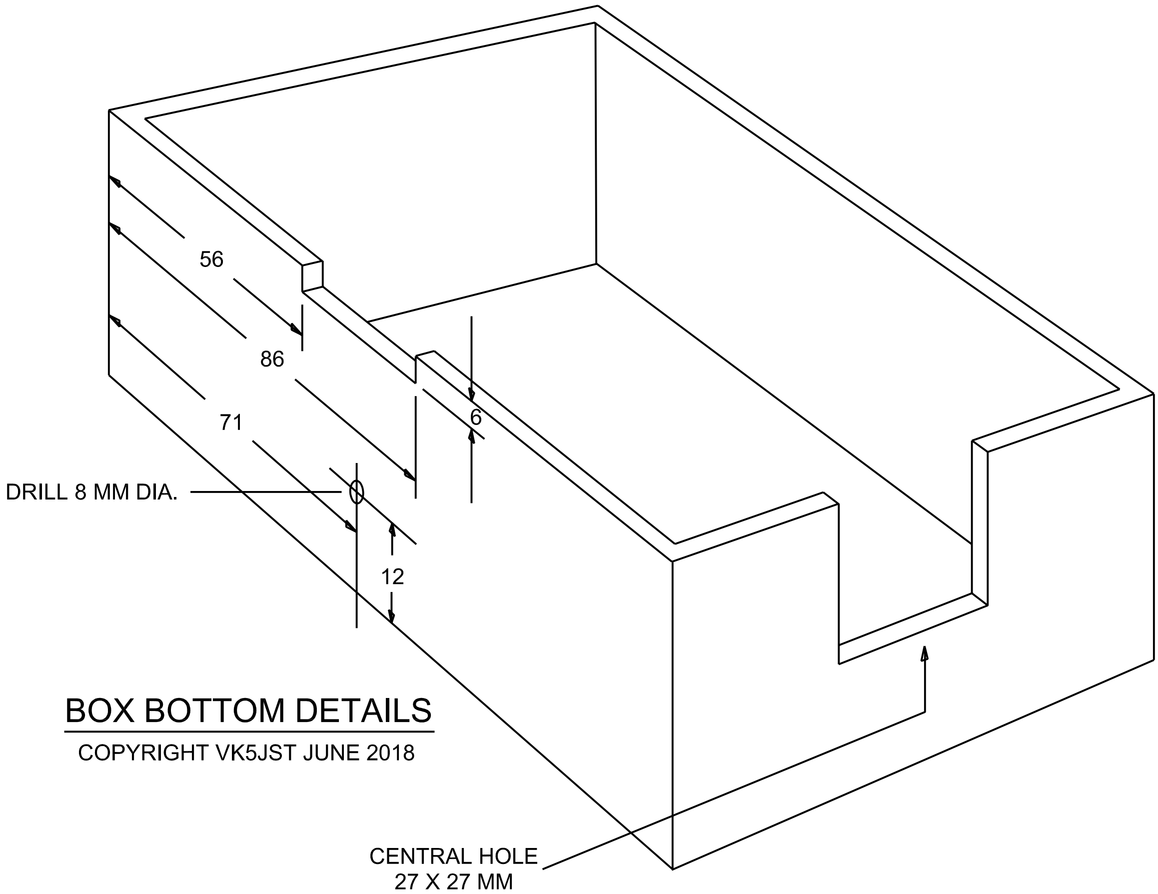
MAIN PCB COMPONENT OVERLAY



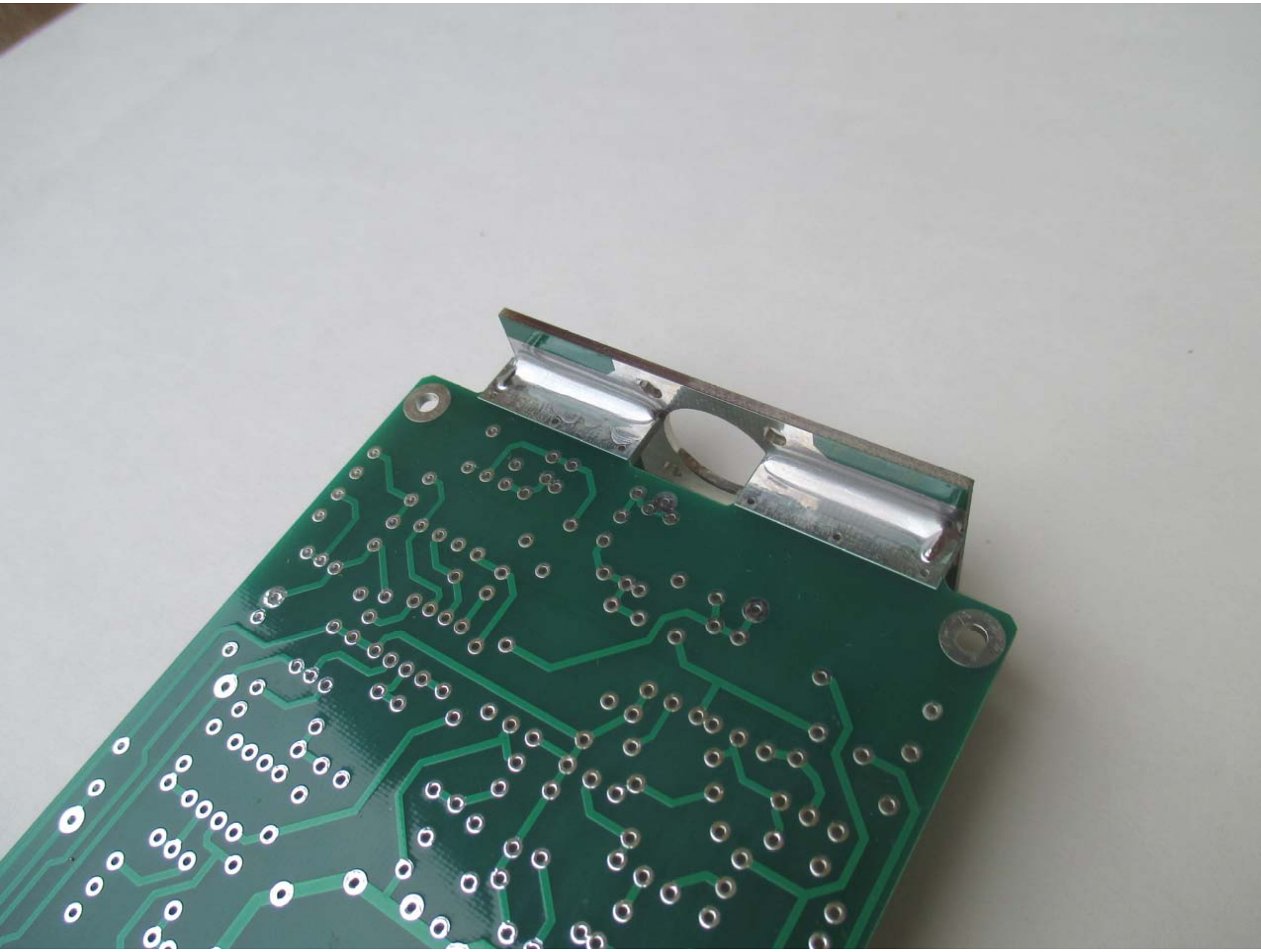
ASSEMBLING MAIN AND CONNECTOR PCBS

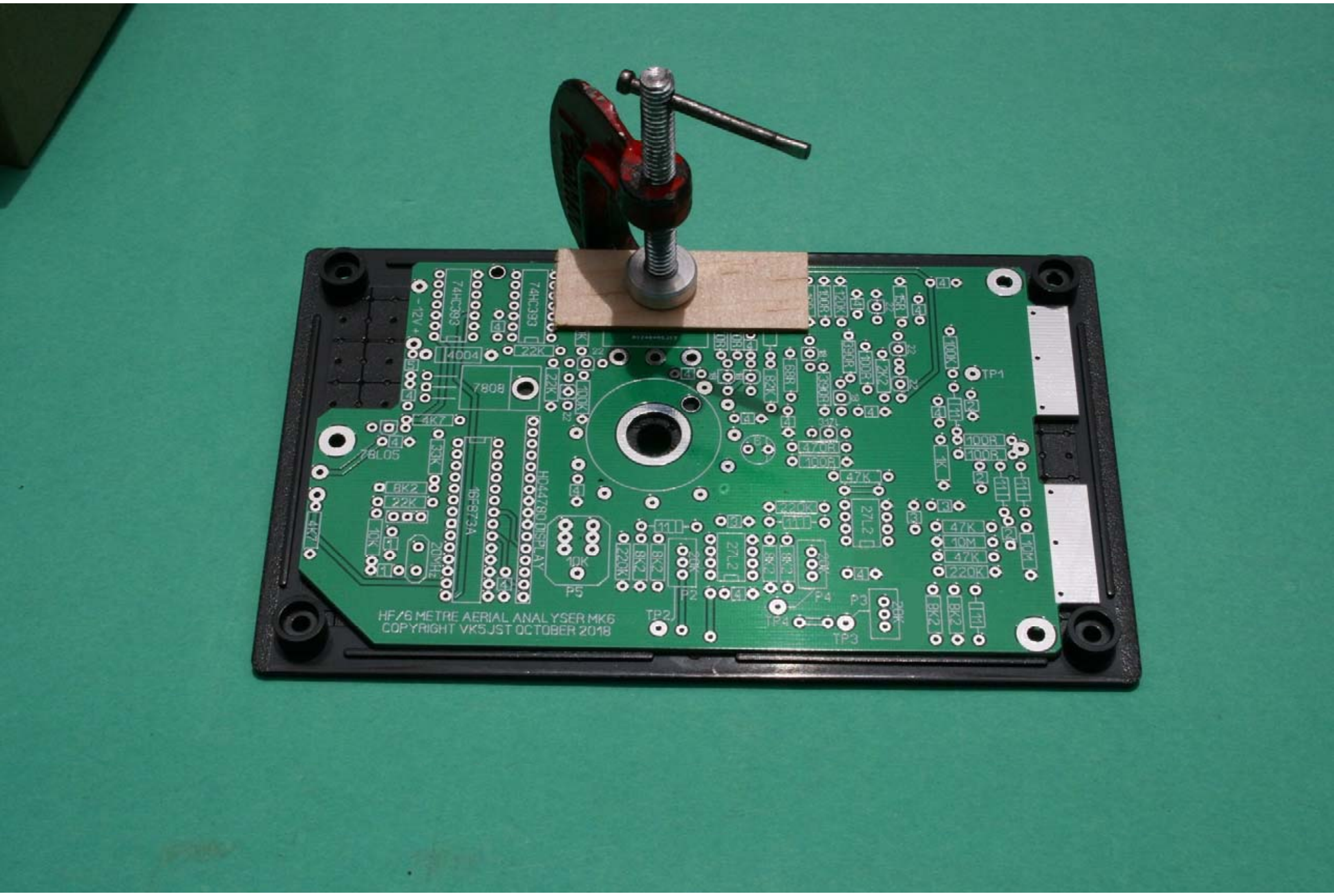


FRONT PANEL DETAILS



BOX BOTTOM DETAILS

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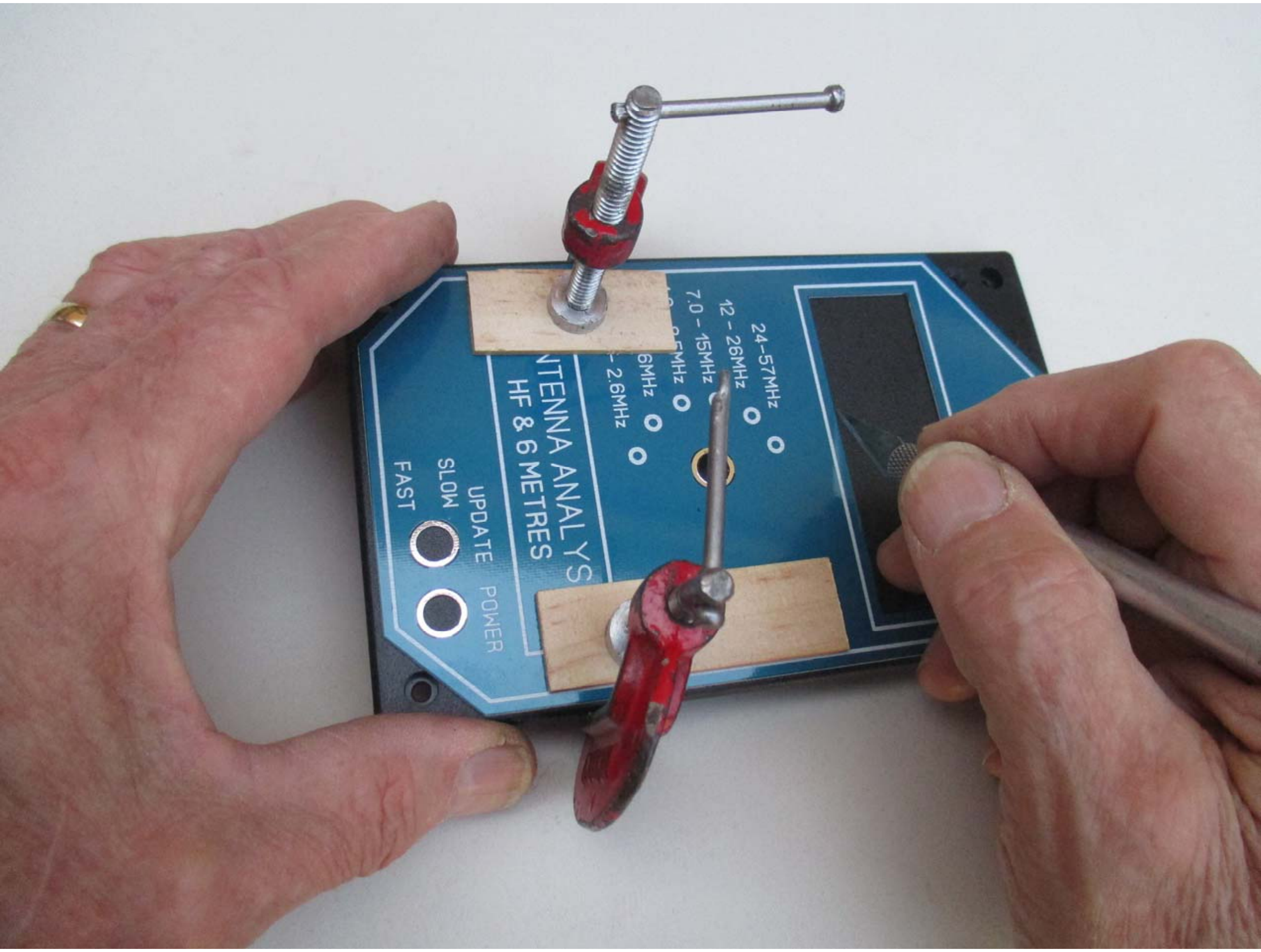
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