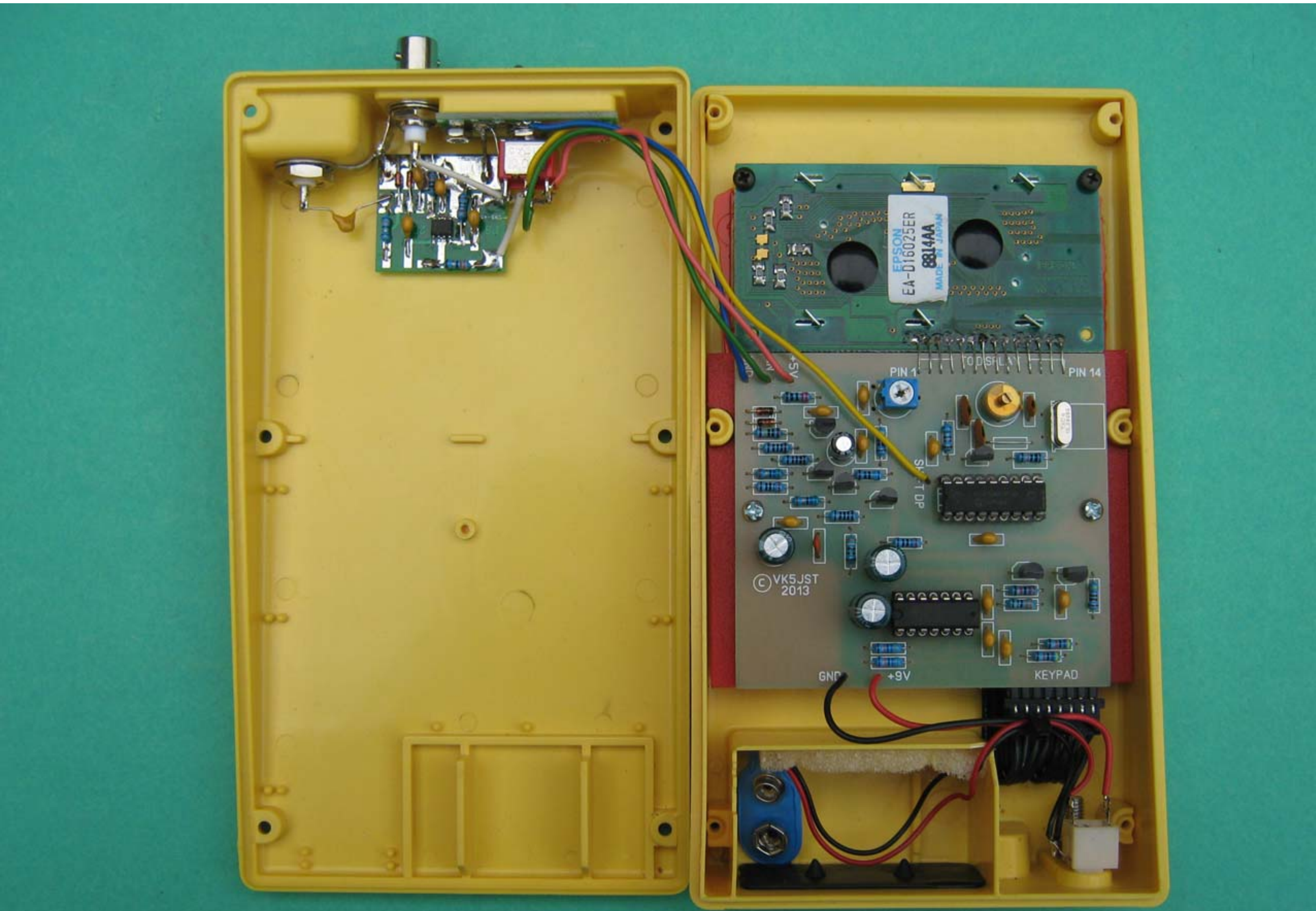

WEATHALERT
796.003400 MHz
READ
AREA
ON OFF


EPSON
EA-D16025ER
MADE IN JAPAN
PIN 1
PIN 14
VK5JST
2013
GND
+9V
KEYPAD

Counter Specifications

<u>Frequency Range</u>
HF Front End….. 20Hz – 50MHz (prototype goes to 100MHz with reduced sensitivity)
VHF Front End…50MHz – 600MHz (prototype goes to 1GHz with reduced sensitivity)

<u>Gating Interval</u>….. 1 second

<u>Input Sensitivity</u>….. See graphs below

<u>Input Protection</u>
HF Front End….. 7 volts RMS continuous max. (1 watt into 50 ohms)
Beyond this level use an X10 passive oscilloscope probe allowing measurements up to 70 volts RMS (100 watts into 50 ohms), or an X100 passive probe (max voltage usually limited by probe to 600 volts RMS).
VHF Front End….. 5 volts RMS continuous max. (0.5 watts into 50 ohms)
Beyond this level use rf power attenuators, or a dummy load with a sampling output.

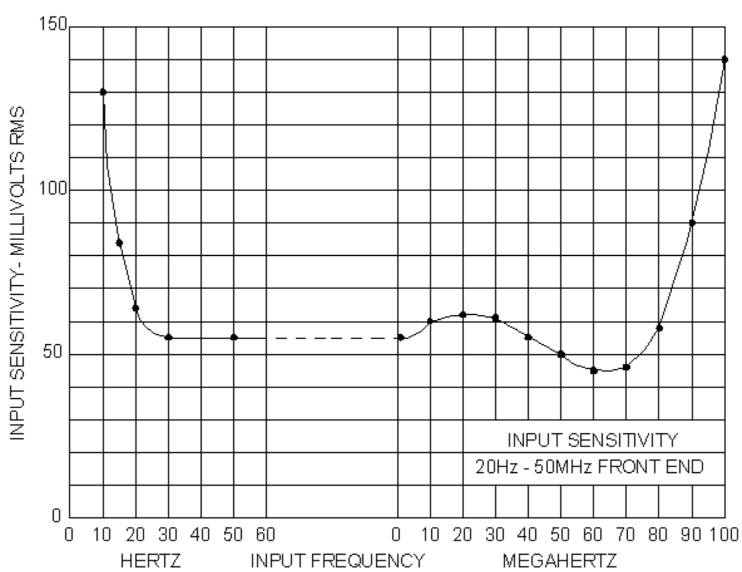
<u>Input Impedance</u>
HF Front End….. 1 Megohm//12pf
VHF Front End….. Nominal 50 ohms when used with 50 ohm through line terminator

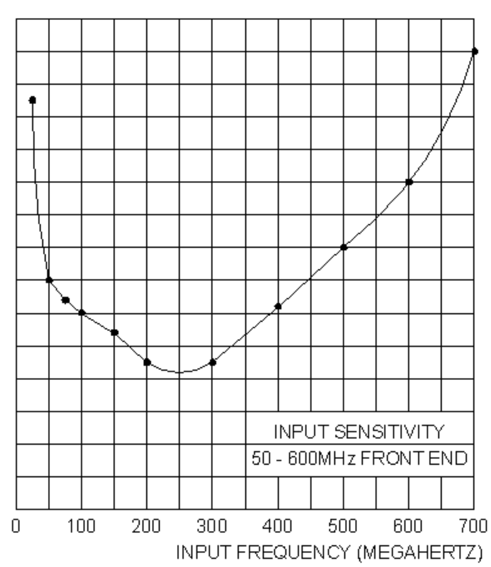
<u>Power requirements</u>….. 9 volts dc @ 34mA (50Mhz range) 42mA (600MHz range)
200 nanoamps in "off" state

<u>Resolution</u>…..8 digits giving 1Hz resolution on HF range and 10Hz on VHF range

<u>Time Base Stability</u>….. +/- 10ppm 0-60C with recommended crystal

<u>General Comments</u>….. Counter may be used with rubber duck antenna to remotely monitor a transmitter output frequency, and operated from an external power source such as a mobile phone wall wart or car battery.





A Really Good 8 Digit 600MHz Frequency Counter for $25 JimTregellas VK5JST

Introduction

Back in 2012, Adelaide Hills Amateur Radio Society (AHARS) acquired some 160 odd Weathalert units which featured a single channel 2 metre receiver and LCD, and were used to advise those in outlying areas of impending threats such as flood or bushfire. These are now obsolete, courtesy of mobile phones and the internet, and so there are a lot around at very attractive prices. So here was a challenge for AHARS. What could be put into this very cheap and attractive case that would be useful to amateurs? One answer was a portable frequency counter which hopefully would cover all ham bands up to 70cm and with enough precision to ensure that any radio was well within its allocated channel width at VHF.

What eventually evolved was an 8 digit counter which gives 1Hz resolution up to at least 60MHz and with an optional prescaler which gives 10Hz resolution up to at least 600MHz. A 10MHz timebase is used which can be directly replaced by a rubidium or caesium beam standard if desired, and so what results is a genuinely professional specification and not bad value at all for $25. ☺

Basic Theory of Operation

A frequency counter works by counting the number of pulses in a given time. At the end of this “gating interval” the count is stored and passed on to the displays, which are then updated at the end of every following gating interval. Usually the gating interval chosen is 1 second (or a decade submultiple of 1 second) which makes things very easy. Just count for 1 second or 100 milliseconds or maybe even 1 millisecond, put the decimal point in the right place and Bob’s your uncle☺.

However, as is usual in electronics, things are not quite that simple. First we need a front end that can convert almost any normal waveform (sine, triangle, pulse, distorted sine, square wave etc) with a very wide range of possible amplitudes, into a rectangular waveform suitable for driving the 5 volt digital counting logic. This front end must be AC coupled to get rid of any dc level in the input signal, and needs a lot of wideband gain to bring small signals up to reasonable levels (typically 1volt peak to peak). Its overload characteristics must be first class so that it can handle big inputs without doing strange things like frequency doubling, and excellent overload protection must be provided so that it cannot be damaged by huge inputs. Following this front end is a circuit called a “Schmitt trigger”. This takes the output of the front end amplifier, with its slow rise and fall times, and by using positive feedback, produces a nice clean rectangular waveform with the fixed amplitude and very fast rise and fall times necessary to drive the following counting logic properly.

As well as doing all of the above, the counter front end should offer industry standard input impedances, which are 1 megohm in parallel with 12pf or so up to around 50 MHz and about 50ohms beyond this frequency. These input specs. allow the use of a standard X10 passive CRO probe at HF to handle really big signals, or a direct interface to 50 ohm rf systems.

The last part of a good frequency counter is a precise “time base” from which the “gating interval” is generated. Professional frequency and time standards almost always provide outputs at standard frequencies of 1,5, and 10MHz (1 volt peak to peak into 50 ohms) with 10MHz being the most widely used. The time base in any good counter will use one of these frequencies because it can be simply checked against one of these standards. Cheap imported counters often use weird frequencies like 13MHz, or some odd microprocessor clock frequency which is a power of 2, making it impossible to replace the internal oscillator with an external frequency standard, and harder to precisely set up.

Coming now to the circuit, the counter has been built around a 16F628A microprocessor. When I started on this project, I first looked around the ‘net, and at back issues of various magazines for ideas. And there it was, a very clever piece of work by Phil Rice VK3BHR. On the net Phil describes a counter inspired by IK3OIL which is an updated version of his unit published in AR of September 2002. This counter uses a very simple front end and a very basic 4 MHz timebase made using an inverter inside the micro. It counts to around 40MHz with reasonable sensitivity. It is very cheap, but none of this is the really clever bit. What is uniquely ingenious is the software inside the micro. No one else has even come close to writing software like this, which does everything digital inside a single cheap chip except for providing a precision timebase. All display driving, and all counting functions including provision of the input gating and Schmitt trigger functions are there. So rather than reinvent the wheel, I emailed him. And got instant cooperation . Code was changed so that a 10MHz timebase could be used. Next, additional code was added so that a prescaler could be added. In parallel with this, I developed a really fast front end, a prescaler, power supply and a good external quartz crystal oscillator. The resulting basic counter now counts to well above the 60MHz spec. (many 16F628A’s actually go up to 105MHz) and typically to at least 900 MHz with the prescaler. I think both of us are rather proud of the results of our mutual cooperation.

Circuit details

The prescaler IC1 handles all frequencies above 50MHz and uses a ECL chip by Motorola (MC12080) to divide any incoming signal by 10. Input protection is provided by R1 and D1/D2 which limit the incoming signal to around 1.4 volts peak to peak. Unhappily, high speed emitter coupled logic dividers (ECL) often self oscillate in the absence of an input signal, and R2 sufficiently unbalances the differential amplifier structure in the chip to prevent this. The output of this divider chip is passed on to the HF front end via S1. Note that when the prescaler is not being used, battery supply to it is switched off as a battery saving feature. S1A also switches the logic level on pin 18 of the micro. to shift the decimal point when the prescaler is in use. Note that the input impedance of this circuit is quite high (several Kohm) which has advantages in many rf applications. If you want an input resistance of 50 ohms to correctly terminate a cable, then use a standard 50 ohm through line terminator on the input BNC connector.

The HF front end has a similar structure with input protection again being provided by R5 and D3/D4. A source follower T1 provides a very high input resistance leaving the actual input impedance of 1 megohm/ 12pf to be defined by R6 and the combination of the junction capacitances of T1, D3, and D4. T1 is followed by a wide band amplifier structure usually called a “diplet”(T1 and T2), which is actually a “triplet” in this circuit as it is followed by an emitter follower T4 to give a very low output impedance. Extensive DC feedback via R9 is used to stabilise the operating point, while ac feedback to R10 via R14 determines the gain and bandwidth. Note that transistors with very large transition frequencies and low junction capacitances have been deliberately selected. BC548’s and PN2222’s etc are not suitable.

In turn this front end drives pin 3 of the micro via a current limiting resistor R16. Under internal micro control, pin 3 can either be an input or an output. When used as an input it has Schmitt trigger characteristics and nicely squares up the output of the front end for counting. When counting is over and the ”gate” is shut, pin 3 becomes an output shorting the signal from the front end to ground while the displays are being updated.

As previously detailed, the 16F628A does all counting, display driving, and with its internal counter/timer derives the "gate" interval of 1 second from the clock oscillator input on pin 16.

The external clock oscillator (T5 etc) driving pin 16 uses a grounded collector Colpitts configuration. Unlike the usual cheap clock oscillator made using an internal inverter in the microprocessor, this structure has the both gain and bandwidth to operate a crystal correctly at the industry standard loads of either 20 pf or series resonance. This is not the case if the inverter inside the micro is used, which is operating well outside mid band conditions and is thus not providing the required 180 degrees of phase shift through the amplifier. In turn this means the crystal has to shift significantly off frequency to provide the missing phase shift around the oscillatory loop and so cannot be adjusted to frequency at the specified load conditions. This oscillator is also far more stable than the micro inverter version because the very small temperature and voltage sensitive junction capacitances of T5 are buried nicely in the quite large values of C13 and C14. The frequency stability of the oscillator thus simply depends on the quality of the 10MHz crystal used.

The last part of the circuit is the power supply. Because the Weathalert case has nice front panel touch switches, it was decided that they should be used, rather than knocking the case around and fitting a standard switch.

So two of the touch switches are used to either "set" or "reset " an SR flip flop formed from two cross coupled gates within a 4011 by temporarily placing a "logic low" level on either pin 6 or pin 1. Two following parallel gates increase the current sinking ability of the switch logic. When pins 10/11 go low, T6 goes into saturation and its collector moves up to within 50 millivolts or so of the battery voltage, applying power to IC4 which in turn supplies a regulated 5 volts dc to the counter circuitry.

When the supply is in the "off " state, the current drain is about 200 nanoamps. This means that the battery will exhibit its normal "shelf" life as this current is much lower than the internal leakage currents within the battery. The current drain of the entire counter is a very modest 34mA when on, and so around 6 hours of continuous portable operation can be obtained from a 200mAH NiMH 9 volt battery. Note that the counter can be also operated from a recycled " wall wart". The very small units used to power mobile phones are often available for nothing from your local mobile phone outlet, as they get plenty of trade ins and repairs.

Assembling the Counter

The first thing to do is check the operation of the LCD by applying 9 volts dc to Weathalert unit. Next, prepare the Weathalert box for use by removing the unwanted parts. Undo the six screws which hold the case together and carefully break the case apart at the waterproofed case joint. Remove the rubber weatherproofing cover over the DB15 connector at the case top and undo the connector retaining screws. Remove the two printed circuit boards without damaging the front panel switch assembly or its cable and plug. Carefully retain all screws and nuts. Gently prize the blue piezo buzzer from the front panel.

If you are going to build the complete counter with VHF prescaler, rather than just a basic 60MHz unit which only uses the main printed circuit board, you will need an extra input BNC connector. To install this, use a reamer to open out the spare 3mm hole between the existing BNC connector and the DB15 connector mounting holes. Finally, as shown in the case detail drawings, remove the bolt nearest the case joint in the case top and ream out the remaining hole for the 3.5mm power jack.

Next you should reclaim the 16 character 2 line LCD. Using a pair of pliers, roughly straighten up the gold plated pins which connect the display to its motherboard. Cut the plastic between each pin with sidecutters. Now with a soldering iron and pliers, remove each pin one at a time by heating and pulling from the motherboard side of the assembly. When you are finished, unless you are very lucky, the display and motherboard will still be held together with solder (but not the pins). Protect the display from heat damage by totally covering its back with a piece of aluminium or steel, and break the bond between the two boards by gently heating the back of the motherboard (where the pins were removed) with a hot air gun until the solder melts. Wave the hot air gun from side to side to evenly distribute the heat. Last, use a solder sucker to remove all solder from the plated through holes in the LCD.

Mounting all components on the printed circuit boards is next. There are two possible time bases which can be used, and the component overlay only shows the details for the timebase which uses the standard external crystal oscillator. If you are going to use the 10MHz TCXO option, then all standard crystal oscillator components are left off the pcb. Follow the additional instructions provided on the last page of this document.

In the standard external oscillator you can use virtually any 10MHz crystal that comes to hand, provided it has reasonable frequency /temperature characteristics and ESR (< 40 ohms). There are two standard loads for 10MHz xtals, series resonance and 20 pf. For any parallel resonant crystal, L1 is replaced with a link. For a 20 pf crystal use a value of 27pF NPO for C15. For the 18pf crystal supplied in the kit C15 is a 22pF NPO. For a series resonant crystal, L1 is a 10uH RF choke and C15 is 56pf. If your crystal has a wide adjustment tolerance, C15 may have to be changed to get the oscillator to operate at exactly 10MHz.

Next assemble the prescaler board. The MC12080 surface mount IC goes on first, and then all of the through hole components are neatly added around this chip. Keep the leads on all components as neat and short as possible.

The main counter board is then “stuffed” as the Americans say (I hope not!). Check every component carefully before insertion (measure each resistor with a DVM etc) and don’t bend the component leads over after insertion into the pcb. Doing it this way allows you to easily remedy mistakes without wrecking the pcb during desoldering. Add the LCD to the assembly using neat little U shaped links made up from 0.5mm dia. tinned copper wire. While you are adding these links, keep the edges of the two boards touching so that everything fits the case when you are finished. Use IC sockets. Once again this makes fixing mistakes painless and safe. So that the pcb is ready for final wiring, attach 6 flying leads of 150mm or longer to those points shown in the component overlay. Use light multi-stranded plastic covered wire of various colours. Cut a piece of cardboard or thin plastic sheet to fit neatly between the rear of the main pcb and front panel switch assembly so that these items will be well insulated from each other. Provide cutouts in the cardboard for the case pillars to lock this insulation firmly into position. Connect the front panel keypad to the main board using the keypad cable. Finally screw the main pcb/LCD assembly into position in the case top using the two mounting holes in the pcb, self tapping screws and the mounting pillars provided in the case. Insert both IC’s. You can now test the main assembly by temporarily applying 9 volts dc or so. Tapping the power on/off switch should turn both the counter and the led power indicator on. Tapping the switch next to it will turn the counter off. The other switches are not used. With power applied, an all zero count should be visible after a couple of seconds, and after you adjust the display contrast trimpot.

The assembled prescaler board is then stuck into position in the case bottom section using thick double sided adhesive tape. Next, the smallest printed circuit board is loaded with its DPDT switch and is screwed into the case using the screw holes that were originally used to mount the DB15 connector. Note that the copper side of this board faces into the interior of the case. All wiring is then completed as per the component overlay and your counter is now ready for testing.

Testing

All that remains now, assuming that you have wired the case and assembled the prescaler correctly, is to adjust the counter to correctly read frequency. This is simple, if you have access to a precision frequency standard. In the case of AHARS club members, a 10MHz rubidium standard will be available, and all that is necessary is to connect the HF input of the counter to the standard via a length of coax cable and then adjust the oscillator trimmer capacitor for a correct reading. You can then check operation of the prescaler by switching to the counter VHF input and attaching the "rubber duck" antenna. At a distance of around 1 metre, key your handheld VHF set and you should see the carrier frequency indicated on the counter. More extensive testing to verify sensitivity will require access to a frequency synthesizer.

Those without access to all this wonderful gear will have to use the old tried and true method of "zero beating" against a known frequency standard. You will need a communications receiver tuned to WWV or WWVH on 10MHz. The receiver should be set to receive AM and you should probably do this adjustment at night when HF is at its best. Drape part of the receiver antenna near the counter oscillator. You should hear an audio note which can be adjusted up and down with the counter oscillator trimmer capacitor. Adjust this for "zero beat". As you adjust the trimmer for an ever lower pitched tone, you will ultimately hear a chuffing sound. If the peaks of the chuff occur once per second, then the two oscillators are within 1Hz. Do the best you can. Note that as the temperature moves away from that at which you made the adjustment (around 20C), the indicated frequency on the counter will change. The very best quartz crystals will hold +/- 5 parts per million over a 0- 60 C temperature range (+/-5Hz per MHz) but these crystals are rare and expensive. Crystals which hold +/- 10 ppm or +/- 15ppm are much more common and so your counter could be off frequency at zero Centigrade by as much as 15Hz per MHz. (1.5KHz at 100MHz). This is about the best that current technology can do without going to a TCXO or a crystal mounted in a temperature controlled environment.

If you have gone with the TCXO option, this timebase does considerably better than an oscillator using a "cold" crystal (non temperature controlled) with the AHARS supplied TCXO drifting just 2.5ppm maximum over a –30 to +75C temperature range. Most of this shift occurs at the extremes of the temperature range, and over 0 – 60C, the frequency drift is likely to be less than 1ppm (1Hz/MHz). This lifts the performance of this counter into the truly "professional" class, allowing accuracies which will compete well with names like HP. All you need is an adjustment tool. I made mine out of an old steel bike spoke, grinding the end to square shape of exactly 0.8mm (0.032") using a micrometer as an aid.

Anyway, that completes all construction. Enjoy using the little beast…..

Jim Tregellas VK5JST October 16th 2013

Parts List for Weathalert Frequency Counter

Resistors (all 0.25 watt 5% metal film)- 25 RESISTORS TOTAL
1@ 33R
2@ 56R
1@ 68R
1@ 220R
2@ 270R
1@ 390R
2@ 470R
1@ 680R
1@ 820R
3@ 1K
1@ 3K3
1@ 6K8
1@ 22K
2@ 47K
2@ 100K
2@ 470K
1@ 1M

Trimpots
1@ 10K trimpot type VTU or equivalent

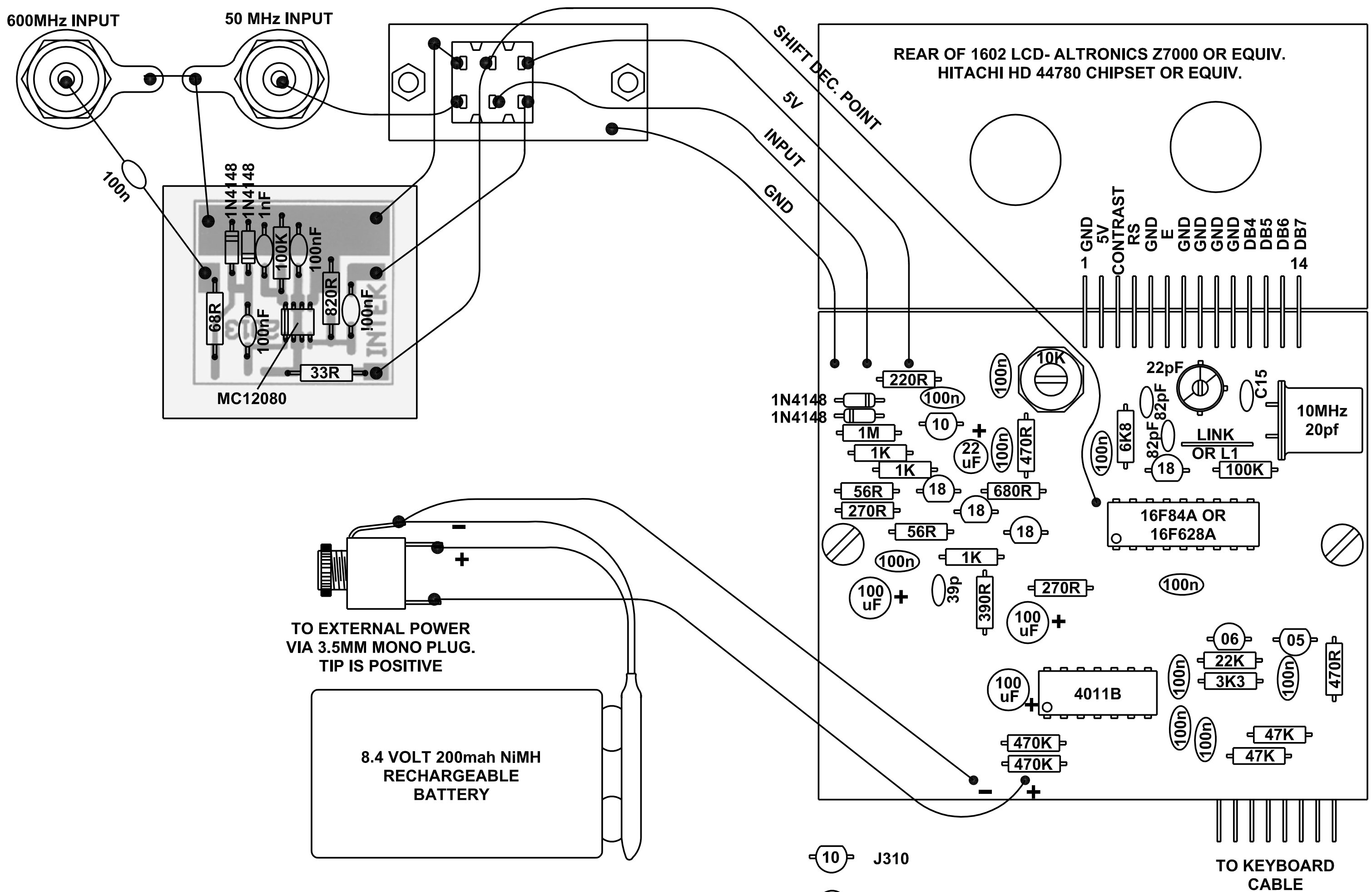
Capacitors
1@ 22pF NPO 50V disc ceramic (18pF crystal only)
1@ 39pF 50V disc ceramic
2@ 82pFNPO 50V disc ceramic
1@ 1nF monolithic multiplate disc ceramic 0.2 inch spacing
14@ 0.1uF monolithic multiplate disc ceramic 0.2 inch spacing
1@ 22uF 25V aluminium electrolytic PC mounting
3@ 100uF 25V aluminium electrolytic PC mounting

Trimmer Capacitors
1@ 22pf Philips (yellow body) or equivalent

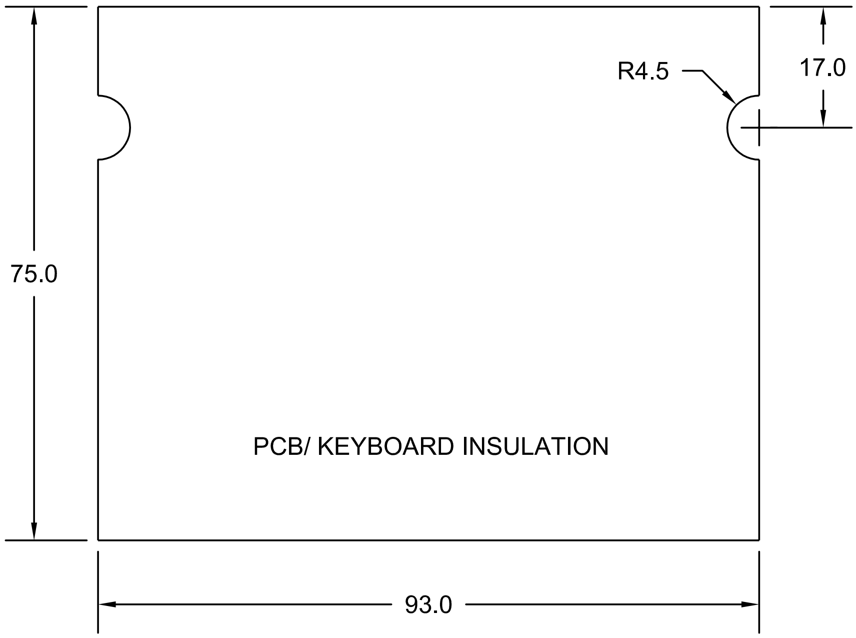
Semiconductors and Sockets
4@ 1N4148
4@ S9018 OR SS9018
1@ J310
1@ 78L05
1@ 4011
1@ 16F628A
1@ MC12080
1@ 14 pin DIL socket
1@ 18 pin DIL socket
1@ PN3906

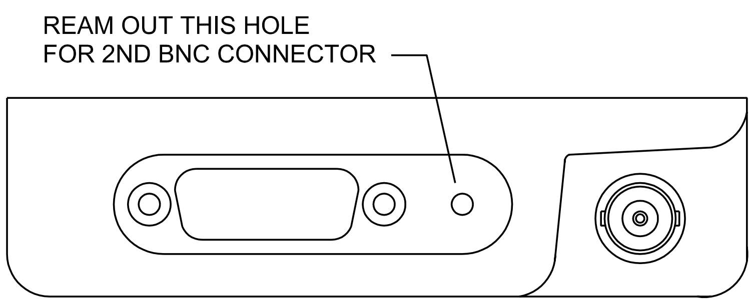
Mechanical
1@ panel mounting BNC socket with nut, spring washer, and solder tag washer
1@ 10MHz 18pf HC49S quartz crystal Element 14 p/n 9B-10.000MEEJ-B
1@ 3.5mm socket with changeover contacts
3@ printed circuit boards
1@ 8.6 or 9V battery
1@ DPDT switch C&K 7201 or equivalent
1@ 500mm length of 0.5mm dia. TCW
1@ 8 pin header strip (from 40 pin snap strip)
1@ 180mm length of rainbow cable or equivalent (6 colours)

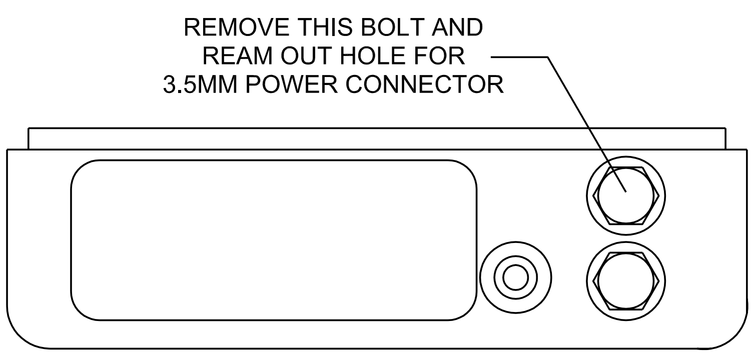
Parts not required (already in Weathalert case) or not normally used
1@ 9 Volt battery snap (in case)
1@ 2 line x 16 character LCD using Toshiba HD44780 chipset or equivalent (in case)
(Altronics Z7000 is a completely compatible high contrast display)
1@ power led (on case switch assembly)
1@ touch switch assembly (in case)
1@ BNC panel mounting socket (in case)
1@ 56pf NPO disc ceramic capacitor (C15-series resonant crystal only)
1@ 10uH RFC (L1 for series crystal only- short out this component for other crystals)
1@ 27pF NPO disc ceramic (C15-20pF crystal only)



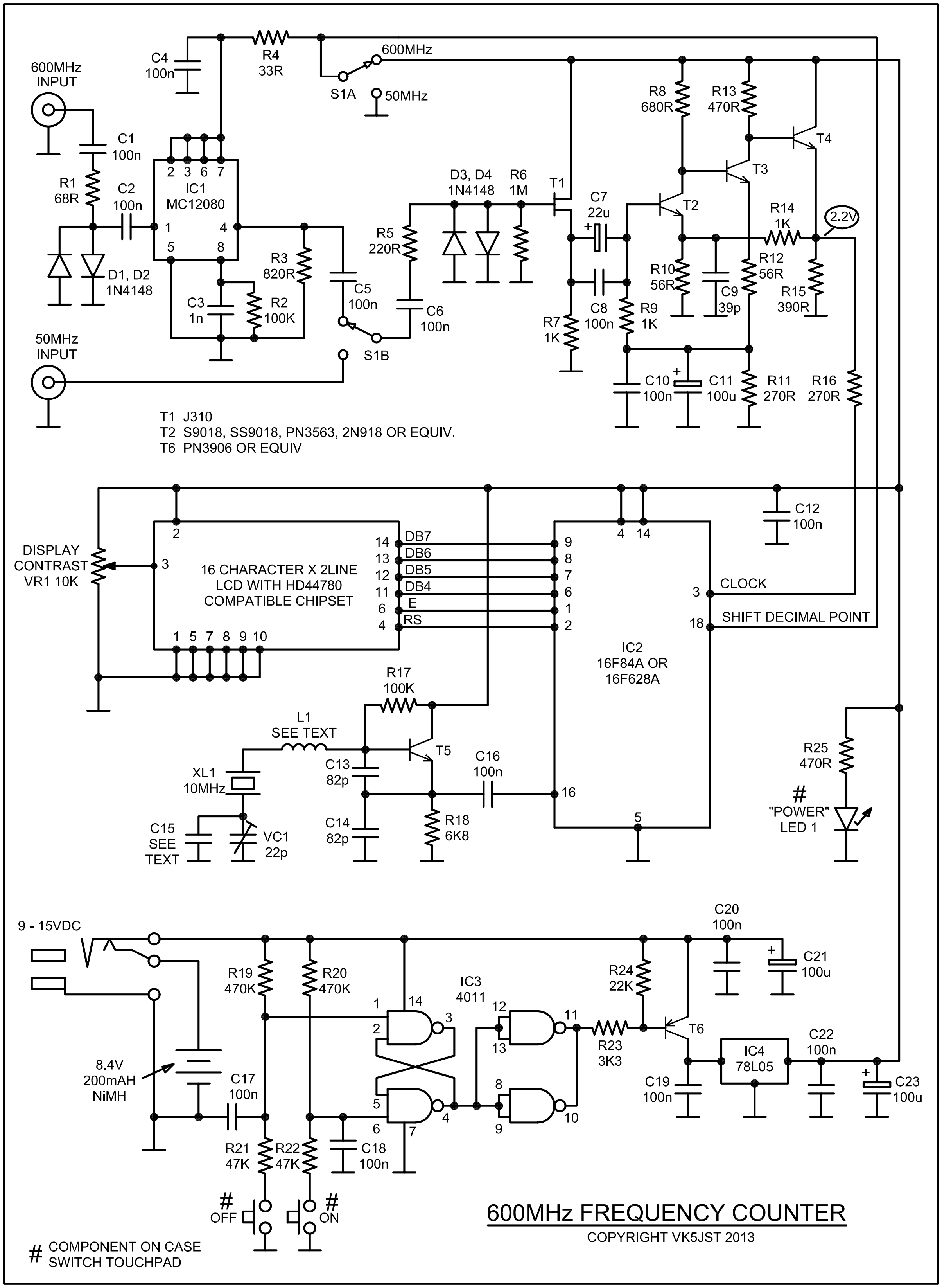
COMPONENT OVERLAY AND WIRING FOR 600MHz PORTABLE FREQUENCY COUNTER







CASE MECHANICAL DETAILS



600MHz INPUT
50MHz INPUT
C4 100n
R4 33R
600MHz
S1A
50MHz
C1 100n
R1 68R
C2 100n
IC1 MC12080
2 3 6 7
1 4
5 8
D1, D2 1N4148
R3 820R
C3 1n
R2 100K
C5 100n
S1B
R5 220R
C6 100n
D3, D4 1N4148
R6 1M
T1
C7 22u
C8 100n
R7 1K
R9 1K
R8 680R
R13 470R
T2
T3
T4
R14 1K
2.2V
R10 56R
C9 39p
R12 56R
R15 390R
C10 100n
C11 100u
R11 270R
R16 270R
T1 J310
T2 S9018, SS9018, PN3563, 2N918 OR EQUIV.
T6 PN3906 OR EQUIV
DISPLAY CONTRAST VR1 10K
16 CHARACTER X 2LINE LCD WITH HD44780 COMPATIBLE CHIPSET
DB7
DB6
DB5
DB4
E
RS
C12 100n
CLOCK
SHIFT DECIMAL POINT
IC2 16F84A OR 16F628A
R17 100K
L1 SEE TEXT
T5
XL1 10MHz
C13 82p
C14 82p
C16 100n
R18 6K8
C15 SEE TEXT
VC1 22p
R25 470R
"POWER" LED 1
9 - 15VDC
C20 100n
C21 100u
R19 470K
R20 470K
IC3 4011
R24 22K
R23 3K3
T6
IC4 78L05
C22 100n
8.4V 200mAH NiMH
C17 100n
C18 100n
C19 100n
C23 100u
R21 47K
R22 47K
OFF
ON
600MHz FREQUENCY COUNTER
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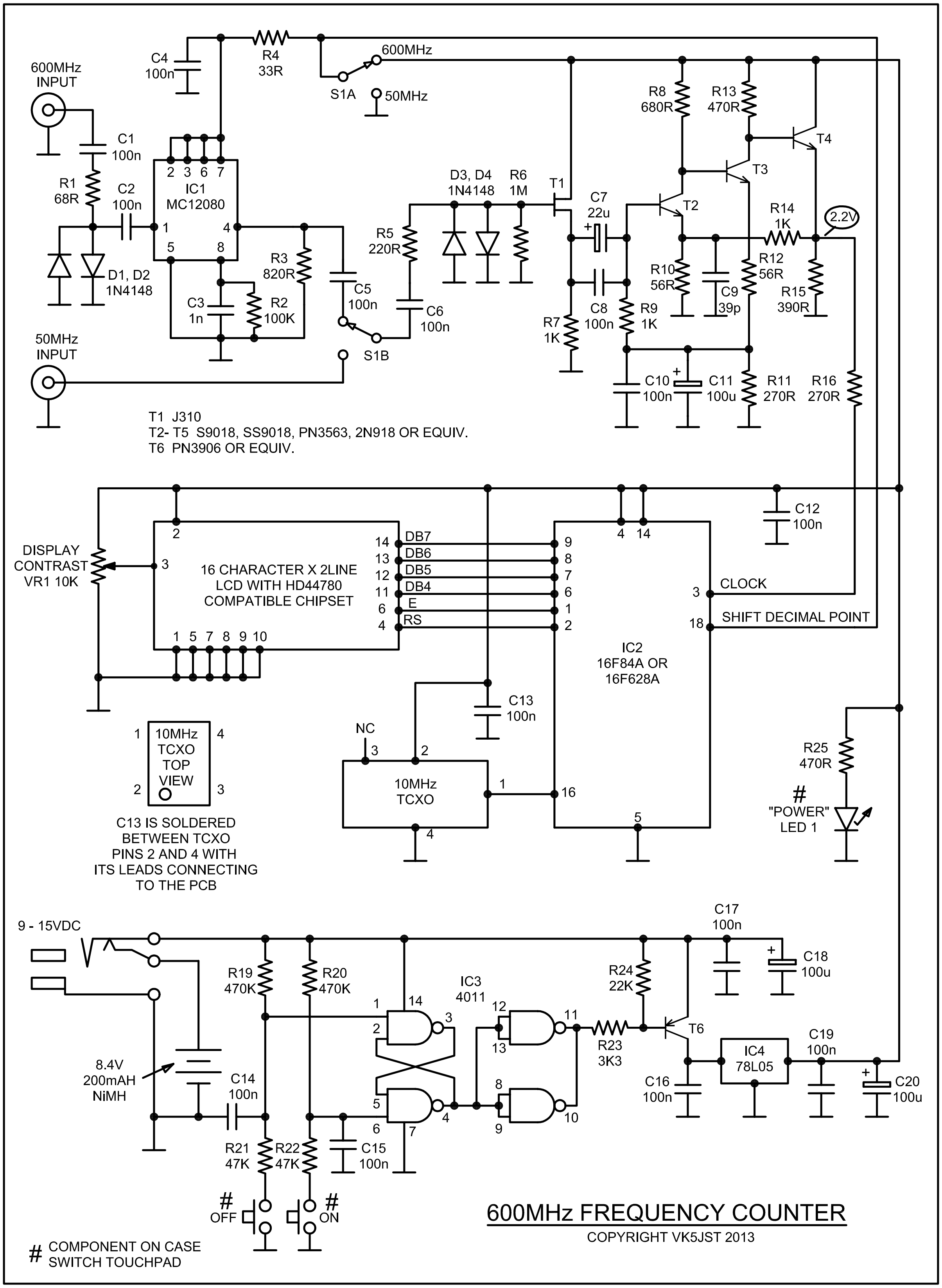
COMPONENT ON CASE SWITCH TOUCHPAD


600MHz INPUT
50MHz INPUT
C1 100n
R1 68R
C2 100n
D1, D2 1N4148
C4 100n
R4 33R
IC1 MC12080
C3 1n
R2 100K
R3 820R
C5 100n
S1A
S1B
600MHz
50MHz
R5 220R
C6 100n
D3, D4 1N4148
R6 1M
T1
C7 22u
C8 100n
R7 1K
R8 680R
R9 1K
R10 56R
C9 39p
R11 270R
R12 56R
R13 470R
R14 1K
R15 390R
R16 270R
C10 100n
C11 100u
T2
T3
T4
2.2V
T1 J310
T2- T5 S9018, SS9018, PN3563, 2N918 OR EQUIV.
T6 PN3906 OR EQUIV.
DISPLAY CONTRAST VR1 10K
16 CHARACTER X 2LINE LCD WITH HD44780 COMPATIBLE CHIPSET
DB7
DB6
DB5
DB4
E
RS
C12 100n
CLOCK
SHIFT DECIMAL POINT
IC2 16F84A OR 16F628A
C13 100n
NC
10MHz TCXO
10MHz TCXO TOP VIEW
C13 IS SOLDERED BETWEEN TCXO PINS 2 AND 4 WITH ITS LEADS CONNECTING TO THE PCB
R25 470R
"POWER" LED 1
9 - 15VDC
8.4V 200mAH NiMH
R19 470K
R20 470K
C14 100n
R21 47K
R22 47K
C15 100n
OFF
ON
IC3 4011
R23 3K3
R24 22K
T6
C16 100n
C17 100n
C18 100u
IC4 78L05
C19 100n
C20 100u
600MHz FREQUENCY COUNTER
COPYRIGHT VK5JST 2013
COMPONENT ON CASE SWITCH TOUCHPAD

The TCXO Option

Using a good temperature controlled crystal oscillator (TCXO) massively improves the performance of the counter, typically giving a time base stability over the normal range of room temperatures encountered of better than +/- 1 part per million (+/- 1Hz/MHz).

To substitute the TCXO for the normal timebase used in the counter, simply leave all standard oscillator components off the main pcb (everything between the LCD and 16F628A).

Mount the TCXO on its small daughterboard, making sure that solder flows under the TCXO to connect its pads with the daughterboard pcb pads. Use scrap bits of resistor lead to connect the daughterboard pads to the main pcb. Three connections are required – to the microprocessor clock input pin and ground and +5 volts. That's it- the photo below shows it all.