

## Frequency counter / Digital Dial

The Digital Dial is primarily intended to be used as a simple means of adding a digital frequency read out to single band QRP radios. A programmable IF offset feature allows the counter to measure the VFO frequency but display the actual operating frequency. The digital dial can also be used as a general purpose frequency counter. It also includes a special “crystal matching” mode, which allows the matching of crystals used in IF filters to within 10 Hz of each other.

### **Specifications:**

Frequency range: 100 kHz to 45 MHz

Resolution: 100 Hz displayed, 50 Hz internal

Update rate: 200 ms

Input level: 50 mv to 100 mv p-p min, 2 V p-p max. (sensitivity varies with freq)

Input impedance: 1 Meg ohm.

Display, four digit LED

Supply voltage: 8 V min, 14 V max

Supply current: 37 ma, typical

Size: 2.1” wide, 1.1” high, 0.5” deep

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Manual updated 6/8/11

## Assembly:

Empty the contents of the static bag into a soup or cereal bowl. This will help keep you from losing any of the small parts.

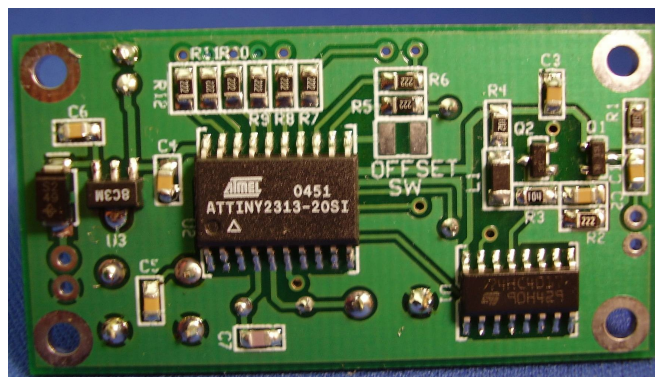
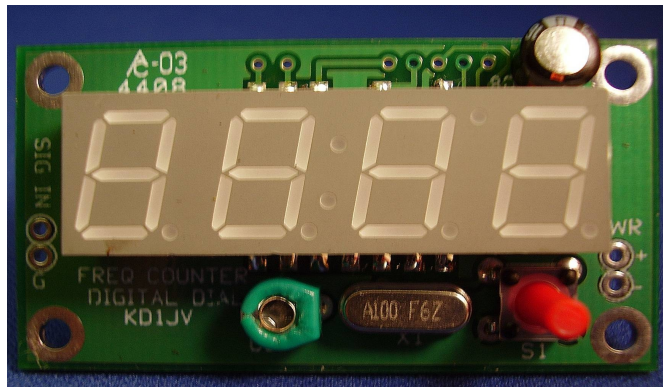
In order to make identifying the SMT parts easier, some of the parts have been color coded. The colors indicated on the layout diagram corresponds to the color marked on the SMT carrier package.

So that you do not mix up the parts, work with only one type of parts at a time. If there is more than one value used, place all of them before moving onto another.

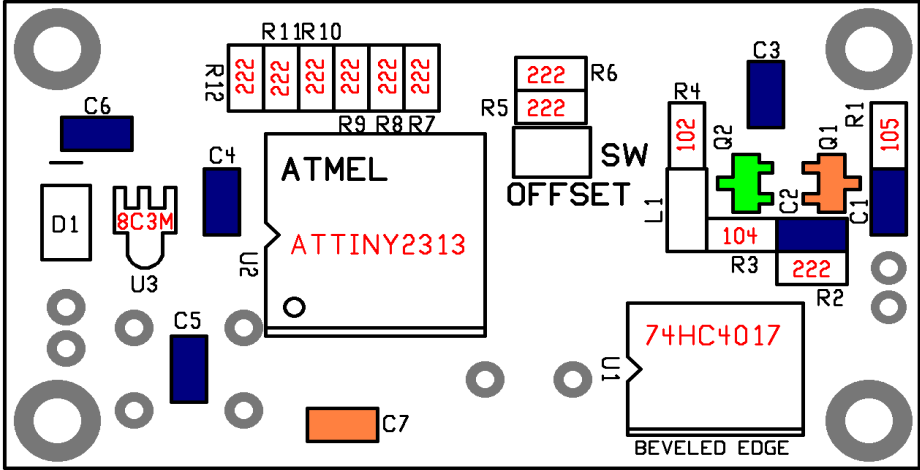
Surface mounted parts are installed first. All of these go on the back side of the board. If this is the first time you've assembled anything using SMT parts, please refer to the "Building with SMT parts" appendix at the end of the manual.

Solder: Do not use your usual solder, which is often 0.032" in diameter. Get some 0.020" solder, silver bearing is best. Radio Shack sell small rolls of this kind of solder.

Use these pictures to help locate and identify parts. Zoom in with the magnifier in the pdf viewer for a closer look.



Assembly: Back side

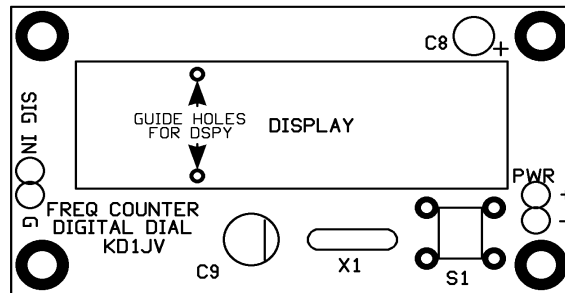


Recommended parts placement order shown in table:

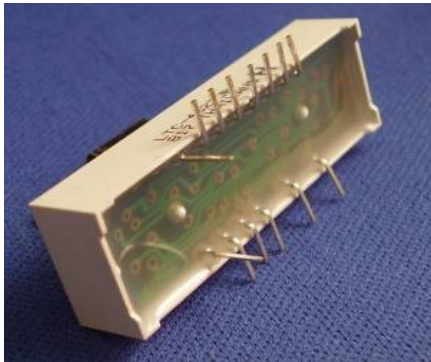
Note: Avoid pushing leads on Q1 and Q2 sideways when soldering, or it can damage the internal connections. Note beveled edge on U1 for proper orientation . Part number will also be in same orientation as shown in diagram. Note white line on D1 package, which will face towards the line above the D1 outline in diagram above.

√	color	location	markings	type	quantity
	ORANGE	Q1	6T N	.j-fet	1
	GREEN	Q2	3C f	NPN	1
	BLUE	C1 to 6	None, tan	0.1 uFd cap	6
	ORANGE	C7	None, tan	22 pFd cap	1
		R2 - R5 to 12	222	2.2K Ω	9
		R1	105	1 Meg	1
		R3	104	100K	1
		R4	102	1K	1
		L1	None, black	4.7 uHy	1
	-----	D1	S2 49	Diode	1
	-----	U1	74HC4017	counter	1
	-----	U2	Tiny2313	MPU	1
	-----	U3	8C3M	5V reg	1

Front side parts:



Display:



The display is soldered into place first. This requires a little rework before it can be done. All *but the two left most pins* need to be bent out at a 90° angle to the body as can be seen in the photo to the left. The part numbering on the side of the display indicates the bottom side, the side which will mount towards S1, X1 and C9. Simply fold the leads over with your thumb or needle nose pliers.

Once the leads are bent over, clip them back about half their length, so that the pins do not go beyond the edge of the pads on the board. Now the display can be soldered to the pads on the board. The two display leads which have not been bent to a right angle go into the two holes in the board as shown in the placement diagram above. This helps to ensure the display will not end up crooked on the board. However, before soldering the pins in place, make sure it is

parallel to the board and the corners of the display are flat to the board.

Once the display is soldered into place, proceed with the four remaining through hole parts.

C9	Green trimmer		
C8	47 uF/ 16V	Long lead +	
X1	10.00 MHz	crystal	
S1	TACT switch		

Note: the flat side of C9 mounts towards the line in the outline on the board.

Assembly of the counter is now complete. Now is a good time to inspect your workmanship and look for any solder connections you might have missed making. Look closely at both ends of the chip resistors and capacitors.

## Test and calibration:

Connect up a power supply, a 9 V battery will do for now. When power is applied, the display should light up with four eights and four decimal points for a couple of seconds. [8.8.8.8] This is the display test.

Once the display test is over, the counter will be in the kHz frequency counter mode. Due to stray pick up by the high impedance input, you will see random numbers flickering on the display. Short the [SIG IN] terminals and the display should now read all zeros. [000.0] Confirm Mode switch operation by clicking and verify display changes to MHz range [00.00] Clicking and holding close the Mode switch for one second should turn off the display. Clicking again turns the display back on.

## Trouble shooting:

There isn't a whole lot which can go wrong with this board. If it does not work first time, there is a 99.999% chance the problem is with the soldering of parts. Therefore, this is what you need to look for first. The other .001% is a misplaced part.

## Calibration:

The counter needs to be calibrated before it will measure accurately. This is done by adjusting the green trimmer on the front of the board. The trimmer has a range of about +/- 700 Hz at 10 MHz. The exact range is dependent on the frequency inputed to the counter. Higher frequencies will have a larger apparent range than lower ones. If no accurate frequency source is available for calibration, centering the trimmer cap in its adjustment range (45 degree turn from factory setting) will put it reasonably close.

An accurate signal source is required and should be done at the highest frequency available, which is in the range of the counter (45 MHz). For most of you, the most accurate signal source you may have available is your commercial "Big Rig", and the highest frequency available will be in the 10 M band. In CW mode, most rigs transmit on the frequency indicated by the dial. You should of course, transmit into a dummy load. If the dummy load is well shielded, you might have to put a coax "T" connector in series with the cable going to the dummy load and add a short "antenna" wire to the tap. With a similar short antenna on the counter input, you will likely get enough signal to get a stable display on the counter. A more reliable method might be to use a resistor divider across the dummy load, say a 100 K in series with a 1 K resistor. The counter input would be connected across the 1 K resistor and the 100 K to the top of the dummy load. Start with as little power output from the rig as possible, then if needed, increase to get a stable reading on the counter.

## Operation:

The digital dial is controlled by a single switch, which we will call the "Mode" switch. This switch may have more than one function, depending on the mode in which the digital dial is being used.

### As a frequency counter:

The first time power is applied to the digital dial, it will power up in the frequency counter mode. Since the counter can count up to 45 MHz and there are only four digits of display, there is a "display shift" function.

On power up, the kHz and 100 Hz digits are displayed. This is indicated by the decimal point being to the right of the third digit. The most significant digit is indicating 100 kHz and the least significant digit is indicating 100 Hz, or .1 kHz.

### To display the MHz digits, click the Mode switch.

The decimal point will now shift the the left one digit, so that it is to the right of the second digit. The display is now indicating 10's of MHz in the most significant digit and 10 kHz in the least significant digit.

## **Sleep Mode:**

In order to reduce current consumption when the counter isn't being used, there is a Sleep Mode function. This turns off the display and powers down the MPU. The input circuits and counter are still under power, so current is reduced to only about 15 ma.

## **Activating Sleep Mode:**

Click and hold the Mode switch for about one (1) second, until the display goes blank.

## **Waking up the display:**

Click the Mode switch again to wake up the MPU and turn the display back on.

## **Using as a Digital Dial:**

In most radios, an IF offset will need to be programmed into the counter in order to indicate the operating frequency of the rig. This is because the IF frequency is often a fractional MHz frequency, such as 4.91520 MHz. If the IF frequency has no fractional component, such as 9.000000 MHz, there is no real need to program an offset, provided one is only interested in reading the kHz part of the operating frequency.

There are three possible combinations of VFO and IF frequencies to obtain the operating frequency. These are:

1.  $VFO + IF = \text{op freq}$
2.  $VFO - IF = \text{op freq}$
3.  $IF - VFO = \text{op freq}$

In the case of #1 and #2, the operating frequency increases as the VFO frequency increases. In the case of #3, the operating frequency increases as the VFO frequency decreases. All three of these cases can be handled by the counter, but you will need to know which combination of VFO and IF mixing your rig uses to program the correct mixing scheme into the counter.

The simplest way to get the IF frequency into the counter is to use the counter to measure the BFO frequency, so this is what we do. However, in a CW rig, the BFO frequency is typically set about 600 Hz higher than the operating or transmit frequency in order to hear the proper CW beat note. In some cases, the BFO will be on the low side of the transmit frequency, but this is rare. In SSB rigs, the BFO will be at the transmit frequency, as there is no offset for SSB reception.

If left uncorrected the BFO CW offset will result in the dial reading 600 Hz higher (or lower) than the transmit frequency. If the receiver has a BFO trimmer (and many do), you can use that to lower the BFO frequency by 600 Hz before programming the offset. This is easy enough to do, since you have the counter connected to the BFO anyway. After programming the offset, re-tune the BFO trimmer.

## **Programming the IF offset:**

The first thing to do is connect the counter to your BFO oscillator. In some rigs, this will be a separate oscillator from the BFO mixer. (Such as 2N2xx rig builders) In many QRP rigs, the BFO oscillator is part of a SA612. In the case of a separate oscillator, connect the signal input to the counter to where the BFO feeds the BFO mixer. In the case of a rig using the SA612, connect the counter to pin 7 of the SA612 (or NE602, SA602) using the supplied 4.7 pfd cap in series with the cable going to the counter. This small capacitor will reduce loading on the oscillator so not to shift the frequency significantly or possibly causing the oscillator to stop working.

The counter should now be indicating the BFO frequency on the display. If it is reading all zeros, then your not getting enough signal and may have to use a larger coupling cap to the counter.

## Entering the IF offset program mode:

The offset program mode is entered by momentarily shorting the two pads on the back of the counter board marked "OFFSET SW" This needs to be done only once, so you can just use a short piece of wire to tap a short across the pads.

Once the two pads marked "OFFSET SW" are shorted together, the display will change to indicate [ LO - - ]

The proper IF offset mode is then selected using the Mode switch on the front of the counter. Each time the switch is clicked, it will advance to the next mode. The display indicates these selections as such:

[ LO - A ] VFO + IF = op freq  
[ LO - b ] VFO - IF = op freq  
[ LO - c ] IF - VFO = op freq  
[ LO - o ] clear offset from memory.

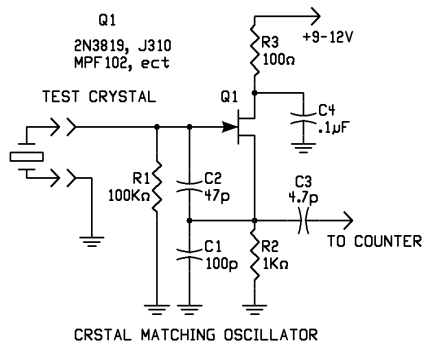
Once the proper selection has been made, click and hold closed the mode switch for one (1) second. If the clear offset was selected, the counter will go back to being a frequency counter. If selection "A" was made, IF+VFO, the frequency reading will be double what it was. If one of the other two modes were selected, the frequency reading will now be zero. If you adjusted the BFO trimmer, reset it now. You can now disconnect the counter from the BFO and connect it to your VFO.

## Connecting the counter to the VFO:

The counter should be connected to the same point as which drives the receiver mixer. If the VFO is not buffered, try using the supplied 4.7p cap in series with the cable going to the counter, at the signal source. If there is enough signal level there to allow using this cap, it will reduce any possible loading effects of the connecting cable. Depending on the VFO frequency and output level, you might have to use a larger value coupling cap to get a stable reading on the counter. For short runs from the VFO to the counter, a twisted pair can be used. For longer runs, say more than 3-4 inches, shield cable, such as RG-174 coax should be used.

## Display multiplexing noise on supply line.

Noise from the display multiplexing on the power supply line and then into the audio of a rig maybe possible. LED segment current has been reduce in this latest version of the DDial, as compared to earlier versions, which has significantly reduced the problem. If however, you do hear noise from the display, adding a series resistor ( 100 ohms to 220 ohms, depending on the supply voltage) and a filter cap at the board side of the series resistor (100 uFd or larger) will eliminate the problem. However, this will increase the minimum supply voltage requirement some.



## Crystal Matching mode:

This mode allows you to match crystals to within 10 Hz of each other. By matching crystals closely, you can build very narrow CW ladder filters. You will of course, need a crystal oscillator to do this. A simple j-fet oscillator circuit is shown to the left.

You may have to tweak the values of C1 and C2 depending on the frequency range of the crystals your using, but the values shown should be good for most of the HF range. The type of JFET used isn't critical, nearly any N channel JFET should work. A socket for the crystals can be part of a dip socket. Since there isn't much to the circuit, it can be built "dead bug", Manhattan Style, or by cutting "island" pads directly onto a copper clad board.

## Entering Matching Mode:

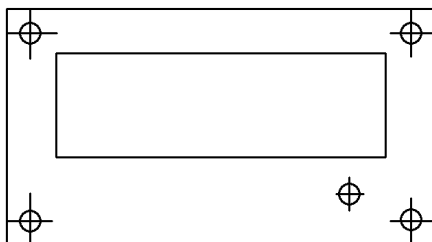
Before entering matching mode, you should check for proper oscillation and frequency of the crystal in the frequency counter mode. Once this is done, remove power from the counter, then click and hold the Mode switch closed and re-apply power to the counter. After the display test of all 8s, the display will read [cr . ], at which time you can release the Mode switch. The counter will be in the crystal match mode, with a 1 second up date time. The display now shows the least significant frequency digits, with the last digit 10 Hz. The decimal point, however does not move from its normal position.

## Crystal matching:

Insert the crystal you want to use as a reference frequency (if it is not already there) and click the Mode switch. This will zero out the display. Remove the "reference" crystal and insert a new crystal to be matched. Allow the oscillator and counter to stabilize for a few seconds. The display will now be indicating the difference (if any) from the reference crystal in 10 Hz increments. Disregard the decimal point, as it has no valid function in this mode. If the difference is negative, the display will indicate a [-] sign as the most significant digit, otherwise the MSD will be blank. Repetitively change crystals in the oscillator, sorting the crystals into groups dependent on their deviation from the "reference" until you have exhausted your supply of crystals. You can return to frequency counter mode by clicking the Mode switch at any time, but you have to re-zero with your reference crystal if you wish to continue matching.

## Mounting the counter board

The drill drawing below can be printed out and used to locate the mounting holes, display cut out and switch location. Cutting the hole for the display can be a problem. The easiest method I've found is to use a Dremal cutting wheel. Using eye protection and a dust mask is recommended while doing this. Small as the counter board is, if your adding it to an existing rig, you may not have enough front panel space to mount it. One option is to mount it into the lid of the rig. The other is to make a little box for the counter and mount that to the lid of the rig. If at all possible, a red filter should be mounted in front of the display. This can be a piece of red transparency film, or some red plastic made specifically for LED display filters. This can be salvaged from an old LED clock radio or the like. Using a red filter will not only make your finished project look better, but will improve the readability of the display.





## Parts List

<i>Location</i>	<i>value</i>	<i>type</i>	<i>qyanity</i>		<i>Ref color</i>
C1-6	0.1 uFd	0805 X7R 10%	(6 pieces)		BLUE
C7	22 pFd	0805 NPO 5%	(1 piece)		Orange
C8	47 uFd /16V	Alum electro	(1 piece)		
C9	30 pFd	Trimmer cap	(1 piece)		
R1	1 Meg	0805 5%	(1 piece)	105	
R2	2.2 K ohm	0805 5%	(1 piece)	222	
R3	100 K ohm	0805 5%	(1 piece)	104	
R4	1000 ohm	0805 5%	(1 piece)	102	
R5-12	2.2 K ohm	0805 5%	(8 pieces)	222	
L1	2.7 uHy	1206	( 1 piece)	inductor	BLACK
U1	74HC4017	SO-16	(1 piece)	/10 counter	
U2	Tiny2313-10	SO-20	(1 piece)	MPU	Atmel
U3	L78L05UAC	SOT-89	(1 piece)	+5V reg	
Q1	MMBF310	SOT-23	(1 piece)	jfet	
Q2	MMBT5179	SOT-23	(1 piece)	NPN 900 MHz	
D1	SS-12	SMT	(1 piece)	1A shottky	
S1	TACT SW	6mm			
X1	10.0000 MHz	HU-49U	(1 piece)	Crystal	
DISPLAY	4 digit LED	LTC-4627	(1 piece)		
pcb	Circuit board				
4.7p	Ceramic disk	To connect to	Signal	Input at signal	source

## How it works:

A signal applied to the counter input is first buffered by a high input impedance J-FET. The signal then goes to a high gain NPN stage, where it is "squared up" so that the frequency can be counted. The inductor in the collector improves gain at higher frequencies, while the resistor is the primary collector load at low frequencies.

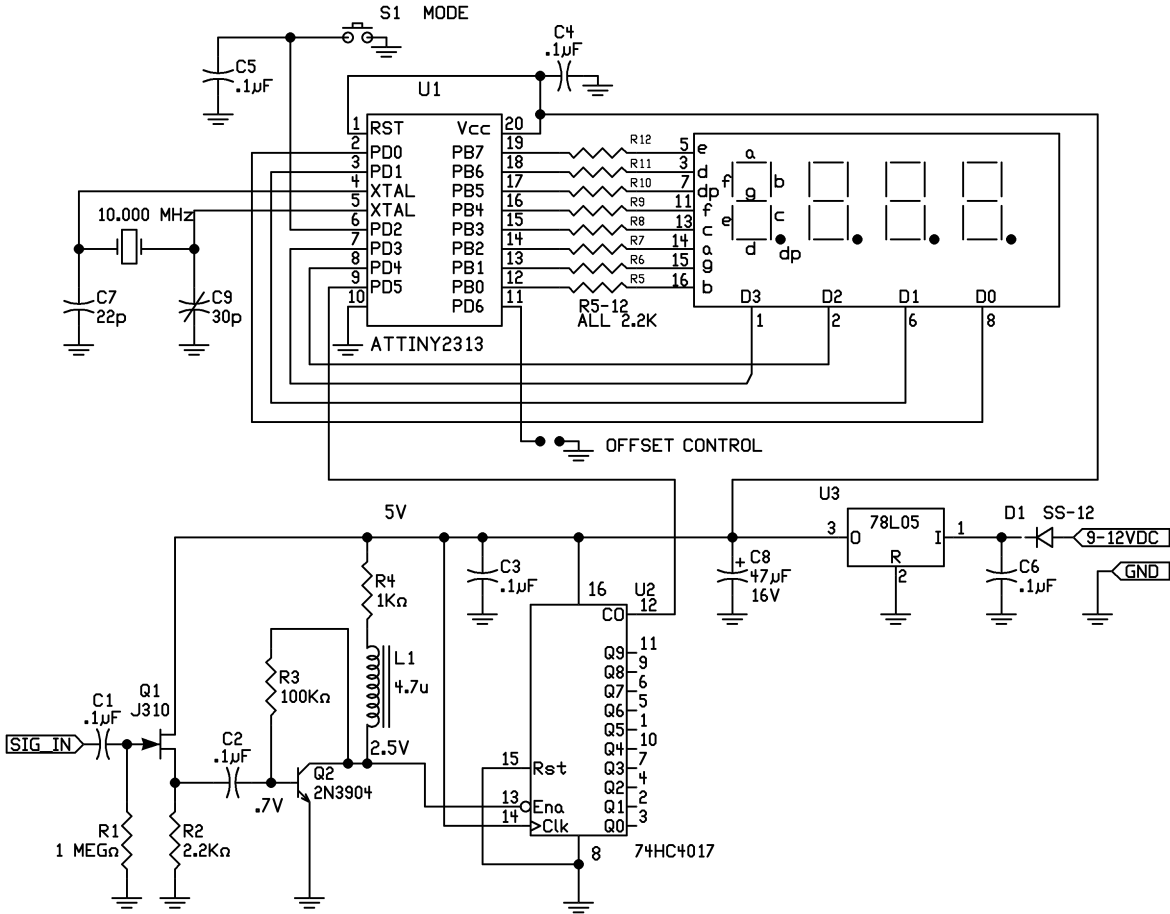
A 74HC4017 is used as a divide by 10 prescaler. The reason for this part is because of the fact the counter input of the MPU is sampled by the MPU system clock. This limits the maximum frequency which can be reliably detected by the MPU external counter input to be  $\frac{1}{2}$  the MPU clock frequency. If the signal were applied directly to the MPU external counter input, the highest frequency we could count would be about 5 MHz, assuming the maximum MPU clock of 10 MHz. By using the /10 prescaler, we can count 10 times higher, or nearly 50 MHz. Because the MPU input sampling isn't in lock with the input signal, in practice the input frequency can't be quite  $\frac{1}{2}$  the MPU clock, but must stay a little below that to get accurate sampling.

From here on out, the Atmel ATTINY2313 MPU ( Micro Processor Unit) does everything. An internal timer allows the external count to be accumulated for 200 ms. A 200 ms conversion time, resulting in 50 Hz count resolution, was chosen so that the frequency display responds quickly to changing frequency input. A 1 second conversion time, while giving 10 Hz resolution, (due to the /10 prescaler) would be too sluggish to be used as a digital dial. In the crystal matching mode, the time base is changed to one second in order to give 10 Hz resolution, as in this case, a slow response time is not a problem.

Once the external frequency count has been accumulated, the resulting binary number is divide by 2 to obtain the final display resolution of 100 Hz. This helps reduce flickering of the 100 Hz digit. Any offsets required are added or subtracted from the count and then the binary number is converted to decimal. The decimal number is then converted to a 7 segment bit code required to display the number on the LED display.

The LED display is multiplexed, that is a number is shown on one of the four digit displays one at a time. This is done at a fast enough rate that it looks like all the digits are on to the eye. The multiplexing or scan rate is about 150 Hz, which is fast enough so that the eye doesn't see flicker, but slow enough noise from the multiplexing is unlikely to get into a rigs audio via the power supply connections. A low current, high efficiency display is used, so that it can be driven directly from the MPU, without the aid of transistor digit drivers.

# Schematic



## **Working with SMT parts:**

If you have never worked with surface mounted parts before, it's not very difficult and can be an enjoyable experience. This section describes the tools and techniques you will need.

### **Tools:**

At a minimum, you will need:

1. Tweezers
2. Magnifier (visor, lighted, hand held glass, etc.)
3. Hobby knife, such as Xacto™ with #11 blade
4. Small tipped soldering iron, ( 1/16" conical or chisel) 25-30 watts or temperature controlled.
5. Needle nose pliers, diagonal cutters, small screw driver.
6. Good light
7. Steady hands.
8. Optional SMT part hold down device.

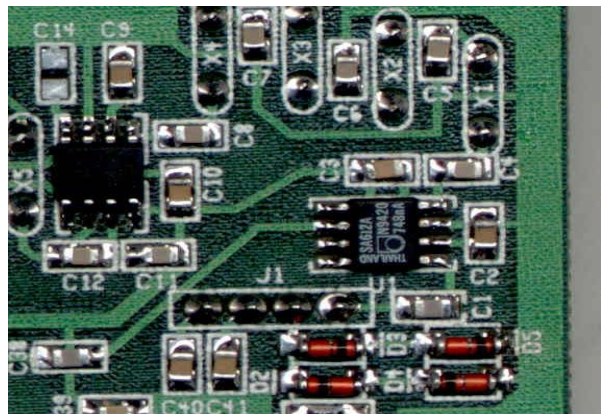
Instead of, or in addition to the tweezers, you can use a tooth pick with a dab of bee's wax on the end to make it sticky. With this, you can pick up the small parts and hold them down while you solder. A problem with tweezers can be if you grasp the part too tightly, it can spring out and go flying, never be seen again.

### **Removing the parts from the carrier**

Many of the parts need to be removed from their carriers before use. A clear strip of plastic needs to be peeled off to expose the part for removal. To avoid losing a part, this is best done by holding the carrier in one hand, in front of you and against your work surface, then peel off the plastic cover using your tweezers. Once the plastic is peeled off, tip the carrier over to drop out the parts in front of you.

### **Soldering:**

Some very thin (.020") solder is supplied with the kit for use with the SMT parts. (If you need more, Radio Shack sells this. Very little solder per connection is needed. Ideally, you want just a tiny concave fillet between the end of the part and the pad. The picture to the left shows examples of SMT soldering.

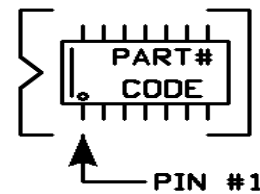


## Chip caps, resistors and other two leaded parts.

1. Lightly tin one of the two pads.
2. Use the tip of your hobby knife or tweezers to peel back the clear cover on the parts carrier and then spill them out onto a clear work space above the board.
3. Pick up the part and place it over the pads. Try to keep it centered and squared over the pads.
4. Apply a little heat with the iron to tack the part to the tined pad.
5. Solder the other end, be sure to heat both the end of the part and the pad at the same time.
6. If needed, return to the tacked end and apply a little fresh solder. Resistors are more likely to need this than capacitors.
7. When placing a number of the same value part to the board, you can speed things up a bit by tinning the pads for several locations at once. Tack the parts down and go back and do the other end. Just be sure not to miss any!

## Finding Pin 1

Some SMT ICs, but not all have pin 1 marked by a dot or dimple, such as their larger through hole versions. In some cases, you have to go by the way in which the printing on the is orientated. When the printing is orientated so that it reads “proper”, i.e., left to right, top to bottom, **Pin 1 is ALWAYS in the LOWER LEFT CORNER.** Often, the manufacturers logo will appear at the pin 1 location, or there maybe a line on the pin 1 end. Pin 1 is mounted on the board facing the notched end of the outline.



## Soldering IC's

1. Lightly tin one corner pad.
2. Place the IC and line up the pins over the pads A little dab of Bee's wax under the chip can help hold it in place.
3. Tack down the corner pin to the tinned pad.
4. Verify the lead alignment on the pads. This is very important!
5. Proceed to solder the rest of the pins to the pads, usually starting at the opposite corner from the one you just tacked down. Ideally, you want a little solder to flow between the IC pin and pad. Therefore, don't hold the IC against the board very tightly, just enough pressure to keep it from moving as you tack the first pin.
6. Don't worry much about making solder shorts, especially with the fine lead spaced parts. See step #7.
7. Inspect the soldering with your magnifying glass. If there are any solder shorts, use solder wick to remove the bridge. Use the tip of the hobby knife to gently "Nudge" the leads. If any of them move, you didn't get them to stick to the pad and need to be touched up.

## **Removing IC's**

Should you ever need to remove a SMT IC, with out damage to the part or the board tracks, this is the way to do it. First, wick as much solder as possible from the leads. Now feed a piece of #32 magnet wire between the leads and the body of the IC. Secure one end of the wire to something on the board. Now grab the free end of the wire and as you heat the first pin on the IC, pull the wire out between the lead and the track. Keep doing this for each pin in line down the chip. Repeat for the other side. The IC will now pretty much just pop off the board. (But you might have to loosen up one or two of the end pins with a tad more heat)

## **Using Liquid Solder Flux:**

Some people like to use liquid solder flux. Since it usually makes a mess, I don't. If you do use it, be sure to clean the board very well afterwards!