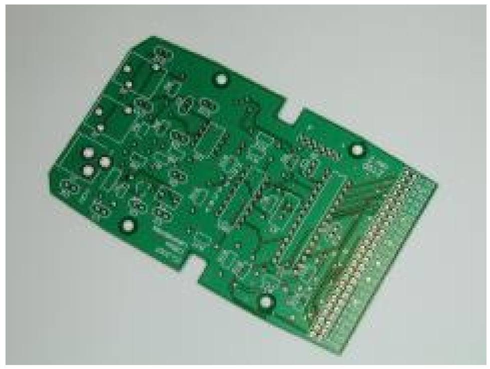
Z100
CW and RTTY Tuning Aid
Assembly and Operations Manual



CLIFTON LABORATORIES

Clifton Laboratories ◆ 7236 Clifton Road ◆ Clifton VA 20124USA ◆ (703) 830-0368

Model Z100 CW and RTTY Tuning Aid

Version 1.41 December 2007

Last Revised 09 December 2007

Warranty
This warranty is effective as of the date of first consumer purchase.

What is covered: During the ninety (90) days after date of purchase, Clifton Laboratories will correct any defects in the Z100 due to defective parts or workmanship (if purchased as an assembled unit) free of charge (post-paid). You must send the unit at your expense to Clifton Laboratories, but we will pay return shipping. Clifton Laboratories' warranty does not extend to defects caused by your incorrect assembly or use of unauthorized parts or materials or construction practices.

What is not covered: If the Z100 is purchased as a kit, this warranty does not cover correction of assembly errors or misalignment; repair of damage caused by misuse, negligence, or builder modifications; or any performance malfunctions involving non-Clifton Laboratories accessory equipment. *The use of acid-core solder, water-soluble flux solder, or any corrosive or conductive flux or solvent will void this warranty in its entirety.* Whether purchased as an assembled unit or as a kit, also not covered is reimbursement for loss of use, inconvenience, customer assembly or alignment time, or cost of unauthorized service.

Limitation of incidental or consequential damages: This warranty does not extend to non-Clifton Laboratories equipment or components used in conjunction with our products. *Any such repair or replacement is the responsibility of the customer. Clifton Laboratories will not be liable for any special, indirect, incidental or consequential damages, including but not limited to any loss of business or profits.*

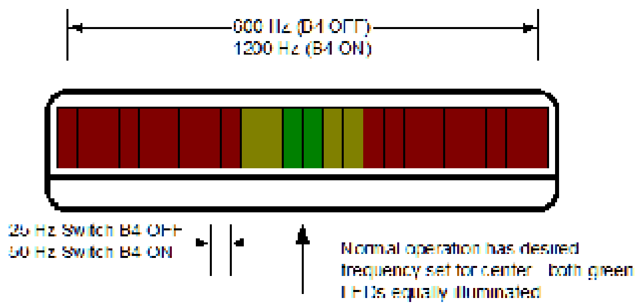
Under no circumstances is Clifton Laboratories liable for damage to your equipment connected to the Z100 resulting from use of the Z100, whether in accordance with the instructions in this Manual or otherwise.

Z100 Tuner Operating Manual & Construction

CLIFTON LABORATORIES

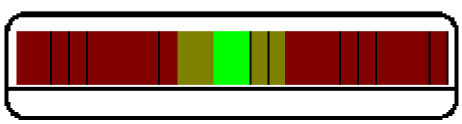
Operation

1. Introduction
   The Z100 is a microcontroller-based frequency display, intended to assist operators in properly tuning in CW and RTTY signals. It provides a graphical display of the current audio frequency in steps of 25 or 50 Hz, using a series of 24 light emitting diodes. The design frequency range is approximately 50 Hz (bottom LED on) through 3 KHz (upper LED). Normal span is 600 Hz (25 Hz/LED) with extended span (1200 Hz) via option switch setting.

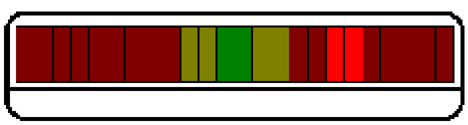


When the frequency is low, diodes to the left of center will be illuminated. Likewise when the frequency is high, diodes to the right of center will be illuminated. The following illustrations assume the Z100 is set for 25 Hz steps.

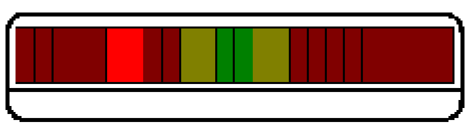
Properly Tuned for CW
center two LEDs equally bright



Audio Frequency 150 Hz High



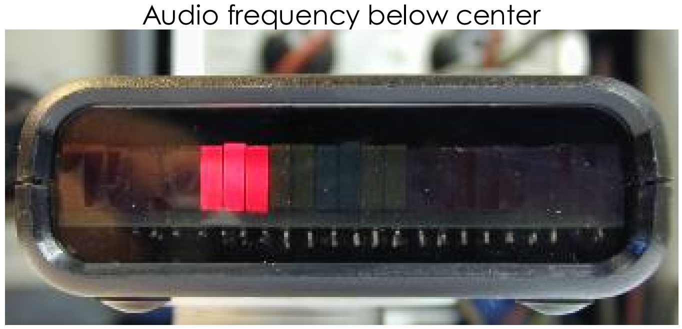
Audio Frequency 150 Hz Low



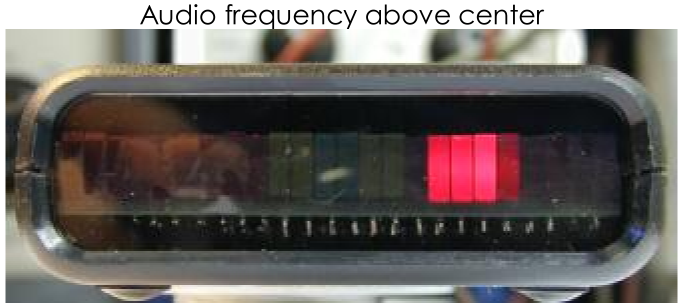
Reproduced in black and white, the drawings may not show sufficient contrast. The photographs below show the same concepts.

Centered correctly

Audio frequency below center



Audio frequency above center



To speed tuning, the center two LEDs are green, whilst two yellow diodes appear on either side of the center green diodes. Thus, the green LEDs will illuminate when the receiver is set within 50 Hz of the correct frequency, and when exactly on frequency both green diodes will appear illuminated about equally. If both the yellow LEDs are on, the frequency error is thus 75 Hz low, assuming 25 Hz steps are selected. If one yellow led and one green LED are illuminated, you are 25 Hz off tune.

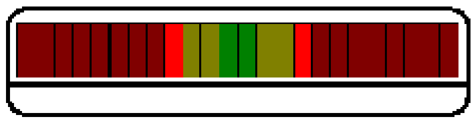
When no signal is present, the receiver's random noise will cause the LEDs to illuminate in a random pattern.

No signal tuned in - just noise
Random LEDs will flicker on

If, of course, your receiver is set for narrow bandwidth, then only a small number of LEDs may illuminate and the distinction between noise and signal will diminish.

If tuning a radio teletype station (RTTY) using the standard170 Hz shift, the two red LEDs just outside the yellow LEDs will illuminate, one indicating mark and the other space frequencies. In addition, the keying sidebands will cause the LEDs on either side of the LEDs corresponding to mark and space to also illuminate, with lesser intensity.

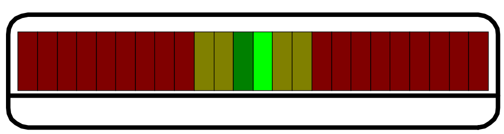
170 HZ RTTY Correctly Tuned with 25 Hz/Step Setting



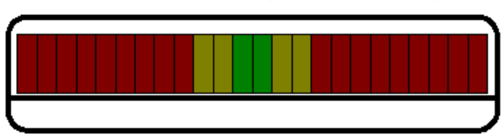
Of course, in normal use, the center frequency used for CW and that used for RTTY reception will differ. The traditional RTTY frequencies of 2125/2295 Hz have a center frequency of 2210 Hz, while the "low shift" standard tones are 1275/1445 Hz, center frequency 1360 Hz. These frequencies may be stored in the Z100's firmware and recalled for later use.

From firmware version 2.1 onward (17 September 2007), the Z100 also has an selectable "tone decoder" mode, which illuminates one green LED when the incoming tone matches the target frequency. When there is no match, no LED is illuminated.

Tone Decoder Mode - Signal Tuned In



Tone Decoder Mode - Signal Incorrectly Tuned



The tone decoder mode bandwidth is approximately 60 Hz.

The Z100 has open firmware and a Z100 purchaser may alter the firmware code. More details are provided later in this Manual.

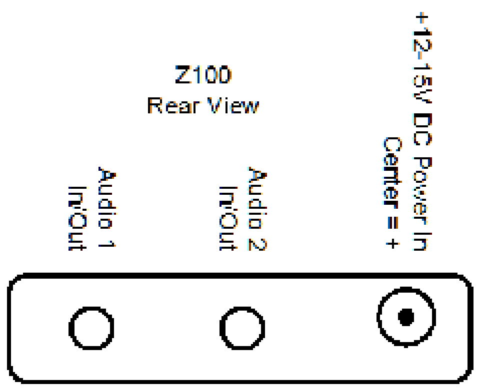
<u>Power-on Test</u>.

When power is applied to the Z100, it performs two tests:

i. The LEDs are sequentially illuminated, from left to right.
ii. Beginning with firmware version 2.1, the LEDs flash the firmware revsion. The major revision number is flashed by one yellow LED to the left of center. The minor revision number is flashed by one red LED to the right of center.

2. Connection

The Z100 has three connection ports on the rear:

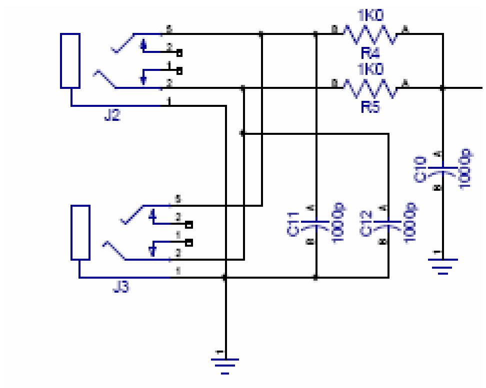


a. Power—a 5.5mm/2.1mm standard coaxial power connector. Center is positive and should be connected to a source of DC power in the range 7 to 15 volts. The nominal input voltage is 12V at approximately 50 mA.

b. Audio input & output—Two 3.5mm stereo jacks are provided. They are wired in parallel, so either may be used as the input, with the other jack becoming the output. Or, you could use the Z100 with two receivers, provided that only one has audio output at a time.

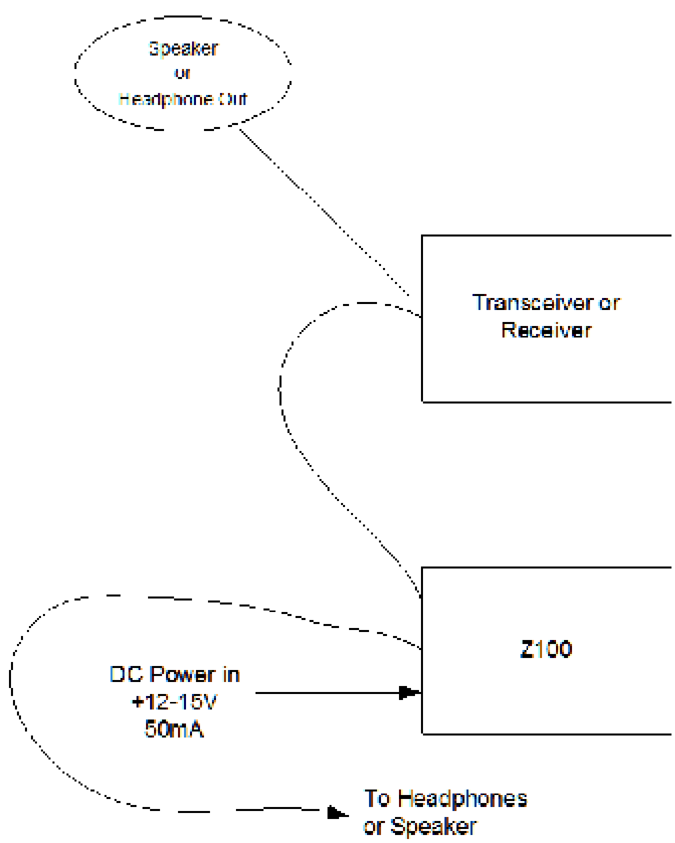
   The Z100 includes a high gain limiter circuit, so it is relatively insensitive to input levels. Full limiting is achieved with well under 25mV RMS. Maximum audio levels should be limited to 5V RMS. This will normally be well above comfortable listening levels for either headphones or speaker. The input impedance is 1 Kohm. Should the Z100 be used with high impedance headphones (> 100 ohms), it may be desirable to modify certain input circuit components for improved channel-to-channel isolation on the bridged input connections, as covered later in this manual.

   The following schematic fragment shows how the two audio input jacks are paralleled and how audio is coupled to the Z100's input stage. As shown, audio on both the sleeve-tip or sleeve-ring circuits are simultaneously available to the Z100's input circuit.



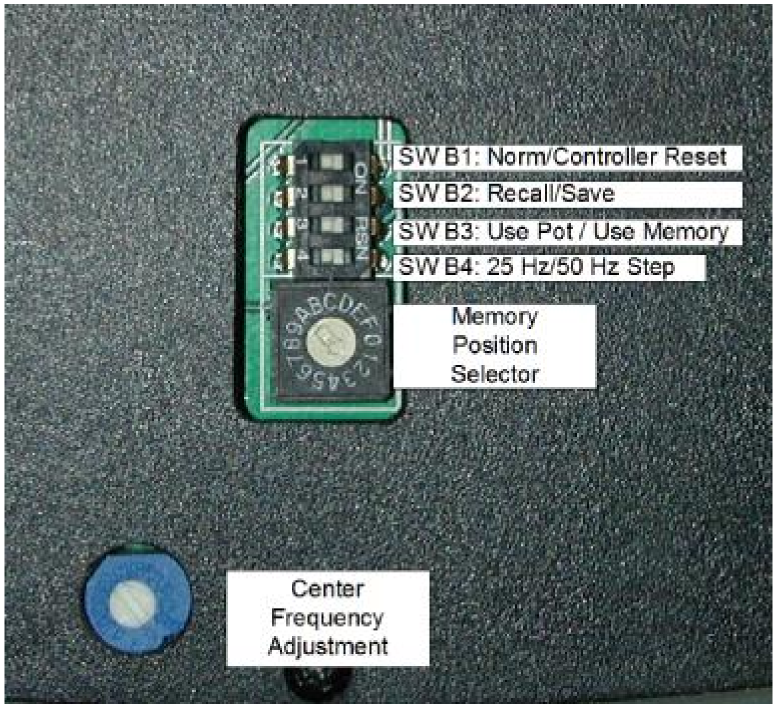
The Z100's design means that these two audio circuits are coupled together through the two 1K resistors, R4 and R5. If this is a problem, and complete isolation of the two audio paths is necessary, either R4 or R5 may be omitted during assembly. Of course, this means that only one audio channel will be available for the Z100's input.

The normal mode of operation is to connect one of the Z100 audio ports to the receivers' speaker or headphone port, or to the line out audio. If desired, the speaker or headphone may be plugged into the Z100's second audio port.



3. Operation

The Z100 is normally controlled via a single potentiometer for frequency center selection and two switches on the bottom of the unit.



a. The switch parameters are:

Switch A is a 16 value rotary switch, with positions 0…F. This switch selects the memory location in which center frequency settings may be saved or recalled.

Switch B is a 4 position DIP switch which controls the Z100's operational characteristics:

Position	Function when OFF	Function when ON
1	Normal microcontroller functionality operation	Reset microcontroller. Used when programming with boot-loader to provide momentary reset for Loader software handshake.
2	Recall center frequency from memory.	Save current center frequency to memory address set by Switch B.
3	Center frequency is determined by the current position of the potentiometer.	Recall center frequency from memory locations 0…F as defined via Switch A's setting
4	25 Hz step per LED	50 Hz step per LED

Switches 2 and 3 govern the Z100's three modes as follows:

Mode 1: Normal operation; the center frequency is based upon the current potentiometer settings.

Mode 2: Base the center frequency upon a previously stored memory position.

Mode 3: Adjust the center frequency using the potentiometer and save the pot setting to the prescribed memory position.

Normally, either Mode 1 or Mode 2 will be used; Mode 3 is only used when filling the memory positions with your custom center frequency settings.

To Operate with the Potentiometer Controlling the Center Frequency (Mode 1)

i. Set B.2 = Off
ii. Set B.3 = Off
iii. Adjust the center frequency as desired with the potentiometer.

To operate with a Saved Frequency (Mode 2)

i. Set B.2 = OFF
ii. Set B.3 = ON
iii. Select the desired saved frequency via rotary switch A

To Store a Frequency to Memory (Mode 3):

i. Apply a signal at the desired frequency to the Z100's audio input.
ii. Set B.2 = OFF
iii. Set B.3 = OFF
iv. Using rotary switch A, set the memory location to the desired address. (Don't forget this step or perform it out of sequence!)
v. Adjust R1, the frequency centering potentiometer, until the frequency is centered*, i.e.,* both green LEDs are about equally illuminated.
vi. Set B.2 = ON
vii. After a second or two, set B.2 = OFF.

It should be noted that only the center frequency is saved and not the frequency step per LED.

To Operate in Tone Decoder Mode

i. Apply a signal at the desired frequency to the Z100's audio input.
ii. Set rotary switch A to position 0.
iii. Adjust R1, the frequency centering potentiometer, until one of the green LEDs is on steadily. As you approach the frequency, you will find that the LED flickers.
iv. Tone decoder mode does not work with memory; only the current potentiometer setting is used to set the center frequency. The B switch settings are ignored in tone decoder mode.

b. Note for K2 Owners.

To calibrate your Z100 for CW operation, you may use the following steps. (This assumes you do not wish to save multiple settings into memory.)

1. Connect the Z100 to your K2 as previously described.
2. Tune the K2 to a quiet spot where no signals are present, such as 28.8 MHz. Set the mode to CW and the filter bandwidth you normally use for CW operating.
3. Set the Z100 switches as follows:
   a. All B slide switches to OFF
   b. Rotary switch to position F
4. Press (not a tap) and release the K2's SPOT button. This generates a continuous tone equal to your desired offset. Adjust the Center Frequency potentiometer on the Z100's bottom until the two green LEDs are about equally illuminated. Press the K2's SPOT button a second time and the spotting tone should vanish. At this time, the Z100's LEDs will randomly flicker as they respond to noise. You are now ready to use the Z100 in your normal CW operating.

This same process may be used to set the tone decoder mode. The normal mode center frequency setting and the tone decoder frequency setting will normally be quite close to each other. However, because of the offset technique used in normal multi-LED mode, you may see a slight offset (typically 12.5 Hz) between frequencies settings in normal and tone decoder mode. Normally, this degree of frequency error is negligible in CW operation.

4. Pre-Programmed Frequencies

The Z100 firmware includes pre-programmed common frequencies. These should be regarded as approximate, due to component tolerance, however.

Switch Position	Center Frequency	Comment
0	None	Tone decoder mode (beginning with firmware release 2.1)
1	100 Hz	Not all lower LEDs will illuminate
2	200 Hz	Not all lower LEDs will illuminate
3	300 Hz	Not all lower LEDs will illuminate
4	400 Hz	Not all lower LEDs will illuminate
5	500 Hz	Not all lower LEDs will illuminate
6	600 Hz	
7	700 Hz	
8	800 Hz	
9	900 Hz	
A	1000 Hz	
B	2210 Hz	For high tone RTTY (2125/2295 Hz) 170 Hz shift
C	1360 Hz	For low tone RTTY (1275/1445 Hz) 170 Hz shift
D	440 Hz	
F	2800 Hz	Highest useful center frequency

At 25 Hz/LED, the lower 11 LEDs represent 275 Hz. Since we cannot have a frequency below zero in this context, when the center frequency is set below 600 Hz, not all LEDs to the left of center will illuminate. This, however, does not stop the Z100 from being useful for tuning of frequencies below 600 Hz; rather this information is provided to explain why some lower LEDs always are dark when the Z100 is set to low tone frequencies.

5. Programming the Z100

The Z100 comes with full firmware source code, written in the Swordfish language. The Z100 firmware is small enough to fit within the free Swordfish Special Edition compiler, available at http://www.sfcompiler.co.uk/swordfish/download/index.html. This allows you to customize the firmware to your liking. It may encourage you to work on other PIC projects using Swordfish.

In addition to the free Swordfish SE compiler, you will need a logic-to-USB adapter cable. The Z100 is intended to be programmed with the FTDI TTL-232R USB to TTL Serial Coverter Cable (5V I/O), available from Mouser Electronics for $20.00, part number 626-DLP-TTL-232R.

Note using these tools require the Z100's PIC to have pre-installed boot-loader firmware compatible with Swordfish's Loader utility. The PIC that comes with the Z100 kit has this boot-loader in place, but a PIC purchased elsewhere will not. Of course, other programmers are available and the HEX code produced by Swordfish SE may be programmed into a suitable PIC via other programmers.

The TTL-232R cable has a 6-way header plug on the logic level end. This is connected to the Z100 header with the BLACK wire at header pin 1 and the GREEN wire at header pin 6. These connections should not be reversed as damage to your Z100 or your TTL-232R cable may result.

When initially connected to a Windows PC, it will be necessary to download and install the appropriate driver software from FTDI, located on the web at http://www.ftdichip.com/. Swordfish's MicroCode loader requires "virtual com port" or VCL drivers from FTDI at http://www.ftdichip.com/Drivers/VCP.htm. Note, however, that FTDI's version 2.0 drivers are "unitary" and the installation process must be carefully followed. FTDI provides a detailed installation process and if you follow it carefully, your installation should be trouble-free.

From within Swordfish, select the MicroCode Loader as the programmer. When prompted to reset the microcontroller, briefly turn Switch B.1 ON and then back to OFF. Or, briefly remove the +12V power from the Z100.

For obvious reasons, Clifton Laboratories cannot support Z100's operating with modified code.

The Z100's source code is available from www.cliftonlaboratories.com. The MicroCode boot loader software will be provided to registered Z100 owners upon request to Jack.Smith@cliftonlaboratories.com.

6. Specifications

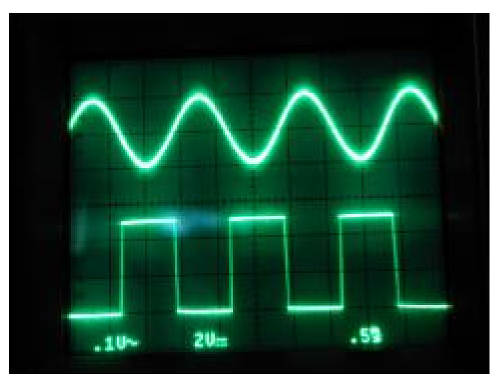
a. Power requirements – 12V DC, 50mA maximum.
b. Number of frequency steps: 24, indicated by red (18), yellow (4) and green (2) light emitting diodes.
c. Frequency step spacing: 25 or 50 Hz
d. Center frequency range – nominal 300 Hz to 3000 Hz.
e. Size: Hammond 1553B enclosure:

Width	Length	Height	Units
3.11	4.62	0.95	Inches
79	117	24	millimeters

f. Programming interface. The PIC 18F2420 has bootloader firmware compatible with Swordfish's MicroLoader. The interface is a 6-way logic level header, for use with an FTDI TTL-232R USB to TTL Serial Converter Cable (5V I/O).
g. Power connector: Standard coaxial power connector, 5.5mm OD, 2.1mm ID.
h. Audio Input: Two 3.5 mm stereo phone jacks. The jacks are wired in parallel to allow pass-across when one is used as input and the other as output. Audio may be applied tip-sleeve or ring-sleeve or tip & ring to sleeve. Typical minimum audio input level is 25mV RMS, and maximum safe audio input is 5V RMS.
i. Number of memory locations for saved center frequency settings: 16

7. <u>Theory of Operation</u>
Audio input is applied to U2, an MCP601 operational amplifier, running open loop to act as a limiter or slicer whereby incoming waveforms are converted to digital form, either logic 0 or logic 1 output. The tip and ring of J2 and J3 are connected through 1K resistors, R4 and R5, to U2's input. R4 and R5 isolate the two audio channels from each other. For RF suppression, the tip and ring inputs are bypassed by 1000 pF capacitors, C11 and C12. Additional bypassing is provided by C10, also 1000 pF.

U2 is biased for single +5V operation by lifting the inverting (Pin 2) and non-inverting (Pin 3) inputs to +2.5V, obtained via a voltage divider (R7 and R6). The +2.5V offset is applied via isolation resistors R8 and R9. The audio is coupled to U2's non-inverting input, whilst U2's inverting input is at AC ground potential, via C7. Thus, a small AC voltage difference between Pins 2 and 3 drives U2's output (Pin 6) between ground and Vdd, +5V.



The illustration at right shows the AC input (upper trace) and U2's output (lower trace.)

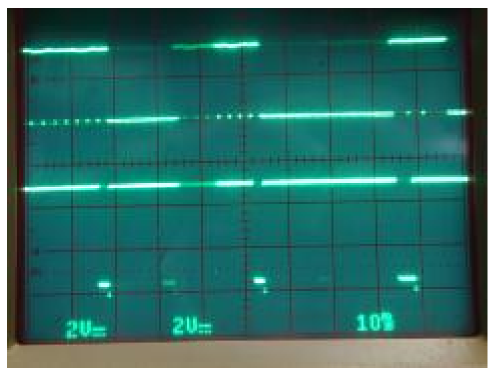
U2's output is applied to a Microchip 18F2420 PIC Microcontroller (other compatible 18F series microcontrollers may be substituted by Clifton Laboratories, depending on availability), running Z100 firmware. The 18F2420 measures the input waveform's negative-going half cycle width using Timer 1. At the 10 MHz clock rate, Timer 1 has 400 ns resolution. The period width is converted to a frequency and then binned into 25 or 50 Hz steps as determined by the option switch settings. The center frequency is computed from either the position of a trim potentiometer coupled to the PIC's A/D converter or by saved center frequency. The firmware then computes which LED should be illuminated for the particular measured frequency and illuminates that LED until the next frequency is read.

The 24 frequency display LEDs are configured in three banks of 8 LEDs, in a matrix arrangement. Banks 0, 1 and 2 are connected to U1's Ports C2, C3 and C4, respectively and to each bank's LED anodes through 43 ohm current limiting resistors (R10, R11 and R12). The cathodes are connected to Port B, pins 0…7.

To illuminate a particular LED, the bank selector is set high (+5V) and the particular LED within the bank has its cathode taken low via the appropriate Port B pin.

Trace 1 (top) is the anode drive (Port C3 in this image) and Trace 2 (bottom) is the cathode drive (Port B7 in this image). This particular combination corresponds to LED D1.7.

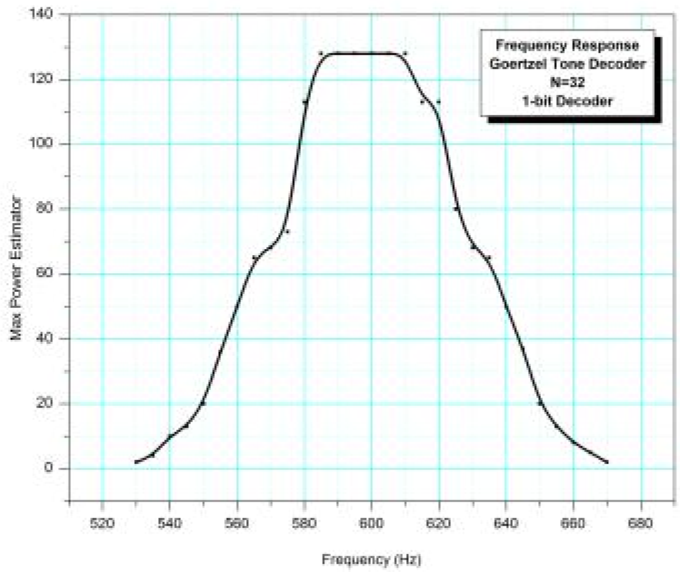
D1.7 is illuminated when the top trace is HIGH and the bottom trace is LOW.



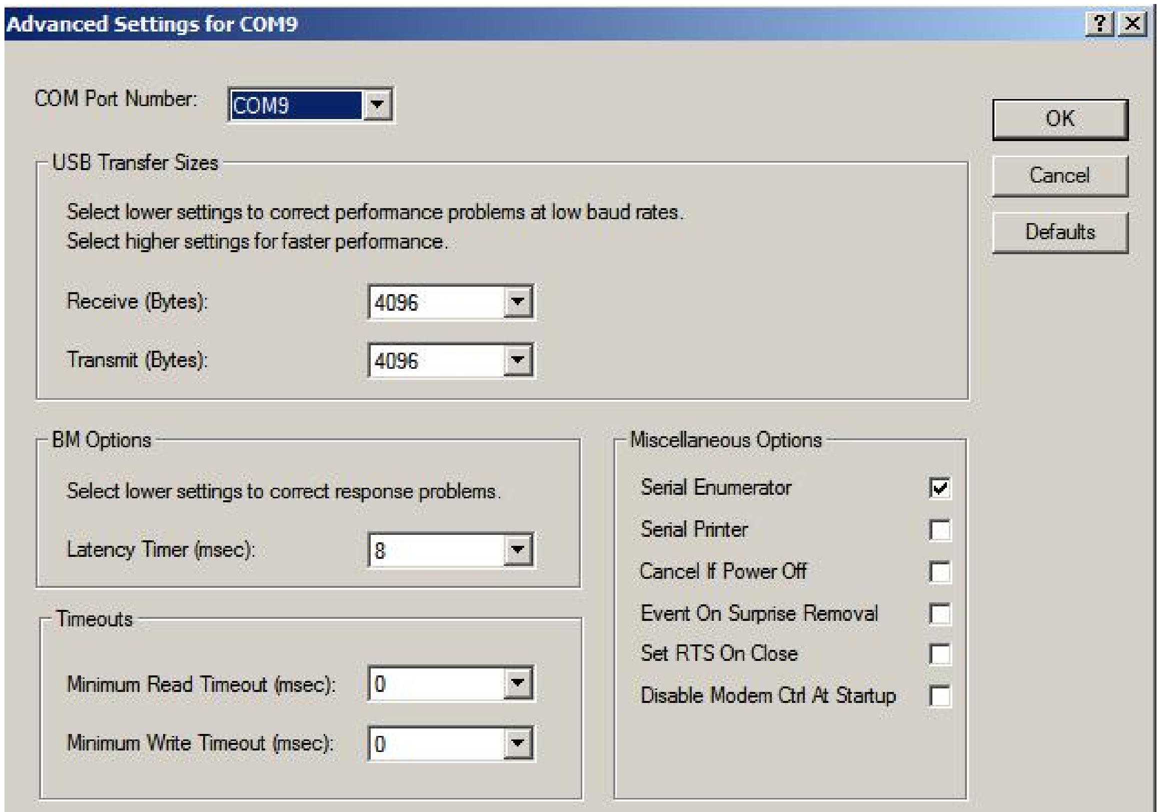
The firmware also allows selection of either 25 or 50 Hz frequency steps and also provides 16 non-volatile memory locations for saved center frequencies. The user may program his choice of frequency into locations 1-F. Location 0 is reserved for tone decoder mode operation.

Tone decoder mode uses a different selectivity algorithm; rather than measuring the audio half-cycle period, it captures 32 samples of the audio level at a rate 4 times the target frequency. The audio level is either 0 or 1, and hence can be considered as a 1-bit A/D. The sampled audio is processed via a Goertzel-based tone detector algorithm.

Since the inbound audio is effectively converted to a square wave, the tone detector algorithm is sensitive to odd-order harmonics, *I,.e.*, if the target frequency is 600 Hz, the decoder will also indicate lock at 1800 Hz, 3000 Hz, 4200 Hz, etc. This is because the square wave contains odd order harmonics of the fundamental frequency, as can be established by a Fourier analysis of a square wave. In normal operation, the user easily distinguishes between 600 Hz and 1800 Hz, so the odd-order harmonic sensitivity is not a significant drawback.



8. Note on Programming
   I found that the FTDI USB serial port requires changing the default Latency Timer from 16 ms to 8 ms in order to successfully program the 18F2420 with Swordfish's MicroLoader. The screen below shows the setting, and it is found under Device Manager for the COM port in question under Advanced Settings, assuming Windows XP operating system is employed.


Advanced Settings for COM9
COM Port Number:
COM9
OK
Cancel
Defaults
USB Transfer Sizes
Select lower settings to correct performance problems at low baud rates.
Select higher settings for faster performance.
Receive (Bytes):
4096
Transmit (Bytes):
4096
BM Options
Select lower settings to correct response problems.
Latency Timer (msec):
8
Timeouts
Minimum Read Timeout (msec):
0
Minimum Write Timeout (msec):
0
Miscellaneous Options
Serial Enumerator
Serial Printer
Cancel If Power Off
Event On Surprise Removal
Set RTS On Close
Disable Modem Ctrl At Startup

Construction

1. Parts List

RefDes	Value	Type	DigiKey, Mouser or Manufacturer's Part Number	Q'ty	Identifier
C1	0u1	Monolithic ceramic cap, 50V or greater, 0.1" lead spacing	BC1084CT-ND		
C2	0u1	ditto	BC1084CT-ND		
C3	0u1	ditto	BC1084CT-ND		
C4	0u1	ditto	BC1084CT-ND		
C5	0u1	ditto	BC1084CT-ND		
C6	0u1	ditto	BC1084CT-ND		
C7	0u1	ditto	BC1084CT-ND		
C8	0u1	ditto	BC1084CT-ND		
C9	0u1	ditto	BC1084CT-ND	9	104
X1	10 MHz	10 MHz resonator	CSTLS10M0G53-B0	1	3 leads, oval shaped body; 10M or 10MZ similar ID
C10	1000p	Ceramic capacitor, 50V or greater; 0.1" lead spacing	B37981M1102K000		
C11	1000p	ditto	B37981M1102K000		
C12	1000p	ditto	B37981M1102K000	3	102
F1	100mA	FUSE; resettable Polyfuse type	RXEF010-ND	1	XF010
R13	10K	1/4w axial carbon film resistor, 5%	CF1/4C103J		
R14	10K	ditto	CF1/4C103J		
R15	10K	ditto	CF1/4C103J		
R16	10K	ditto	CF1/4C103J		
R17	10K	ditto	CF1/4C103J		
R18	10K	ditto	CF1/4C103J		
R19	10K	ditto	CF1/4C103J		
R2	10K	ditto	CF1/4C103J		
R8	10K	ditto	CF1/4C103J		
R9	10K	ditto	CF1/4C103J	10	Bwn-blk-org
R4	1K0	1/4w axial carbon film resistor, 5%	CF1/4C102J		
R5	1K0	ditto	CF1/4C102J	2	Bwn-blk-red
R3	1M	1/4w axial carbon film resistor, 5%	CF1/4C105J	1	Bwn-blk-grn
R10	43R	1/4w axial carbon film resistor, 5%	CF1/4C430J		
R11	43R	ditto	CF1/4C430J		
R12	43R	ditto	CF1/4C430J	3	Yel-org-blk
R6	470R	1/4w axial carbon film resistor, 5%	CF1/4C471J		
R7	470R	ditto	CF1/4C471J	2	Yel-viol-bwn
L1	47uH	RF Choke, 200mA or greater current rating	542-78F470J-RC	1	Yel-viol-blk

R1	5K	5K trimpot, Bourns R3386P case		1	502
U4	78L05	LM78L05ACZ, 5V regulator, TO-92 case	511-L78L05ACZ	1	78L05
U2	MCP601	MCP601, DIP-8	579-MCP601IP	1	MCP601
D1		1N4001, or any similar power diode.	583-1N4001-B	1	
D0.0		Rectangular LED, 0.091 wide	604-WP153HDT		
D0.1		ditto	604-WP153HDT		
D0.2		ditto	604-WP153HDT		
D0.3		ditto	604-WP153HDT		
D0.4		ditto	604-WP153HDT		
D0.5		ditto	604-WP153HDT		
D0.6		ditto	604-WP153HDT		
D0.7		ditto	604-WP153HDT		
D1.0		ditto	604-WP153HDT		
D1.7		ditto	604-WP153HDT		
D2.0		ditto	604-WP153HDT		
D2.1		ditto	604-WP153HDT		
D2.2		ditto	604-WP153HDT		
D2.3		ditto	604-WP153HDT		
D2.4		ditto	604-WP153HDT		
D2.5		ditto	604-WP153HDT		
D2.6		ditto	604-WP153HDT		
D2.7		ditto	604-WP153HDT	18	Red rectangular LED
D1.1		LED	604-WP153YDT		
D1.2		ditto	604-WP153YDT	2	Yellow rectangular LED
D1.3		LED	604-WP153GDT		
D1.4		ditto	604-WP153GDT	2	Green rectangular LED
D1.5		LED	604-WP153YDT		
D1.6		ditto	604-WP153YDT	2	Yellow rectangular LED
J1		DC-POWER	CP-002A	1	none
J3		PG203J	Kobiconn 161-3507		
J2		ditto	Kobiconn 161-3507	2	none
J4		MA06-1	571-6404526	1	6 position male header
SW1		DIP Switch		1	Rotary, 0…F
SW2		DIP Switch		1	4 position on/off
U1		PIC18F2420-PDIP	579-PIC18F2420-I/SP	1	18F2420
U3		Not used			
		Plastic enclosure with hardware Hammond 1553B with holes milled		1	

	Printed circuit board, Z100, Rev 2.B	1
	Cardstock shim stock, approx 0.0085" thick, two lengths	1
	Clear lens for enclosure	1
	Strip gray optical filter film	1
	8 pin DIP socket	1
	28 pin DIP socket 0.3" spacing	1
	Adhesive feet	4
	Condensed instructions adhesive label	1
	Power cable	1
	Audio jumper cable; 3.5mm male stereo both ends	1
	4-40x1/4" stainless steel machine screws	4

2. Note on Component Substitution
    a. For high impedance audio inputs

The Z100's audio input ties the tip and ring audio connections together through R4 and R5 (1000Ω). This allows the Z100 to display mono input or independent audio channel input without user intervention. However, if independent audio is used, only one channel may be active at any time. In addition, 1000 pF RF bypassing capacitors (C10, C11 and C12) are provided.

This arrangement means that the two channels (tip and ring on the connector, or left and right, in the stereo parlance) are bridged together with 2000 ohms and thus a signal in one channel will appear in the other channel at a reduced level.

R4, R5, C10, C11 and C12's values are satisfactory for low impedance speaker and headphone connections, in either mono or stereo mode. However, high impedance connections (say over 100 ohms) may experience unacceptable levels of cross-coupling between the left and right channels, when operated with independent input channels. With 100 ohm input impedance, for example, the cross coupling is approximately -26 dB.

To improve cross coupling for high impedance independent inputs, increase R4 and R5. Suggested starting points are 10K. C10, C11 and C12 should be correspondingly reduced to 100 pF.

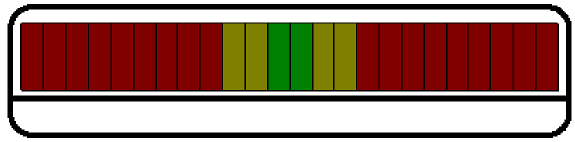
    b. LED Brightness

LED current, and hence brightness, is determined in part by R10, R11 and R12, supplied at 43 ohms. The drive current can be increased slightly by reducing the value of these three resistors from 43 ohms, but the 18F2620 will only source about 25 mA even into a short circuit, so lower resistance will not result in a significant increase in LED brightness. Clifton Laboratories does not recommend reducing R10, R11 and R12 below 43 ohms. These values may be increased, should reduced brightness be desired.

    c. LED Order

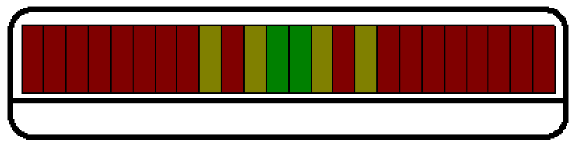
For normal CW and RTTY operation, the normal LED assembly order places the two green LEDs in the centermost position, flanked by two yellow LEDs on either side with red LEDs filling the remaining positions.

Normal Assembly



For specialized applications, this order may be altered. For example, if the normal mode of operation is 170 Hz shift RTTY, it might be desirable to place the green LEDs where they will be alternately illuminated by the mark and space frequencies. Or, perhaps use two yellow diodes in that position, reserving the green LEDs for the center, as shown below.

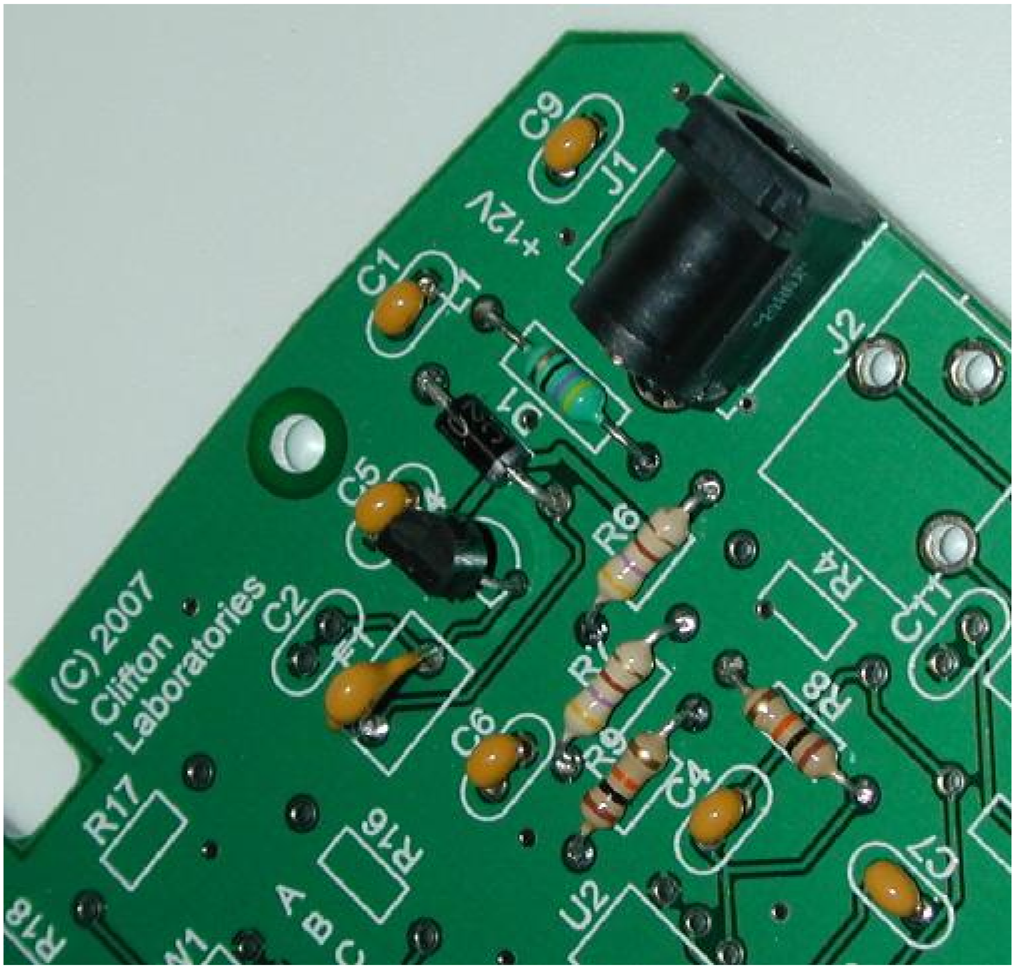
Possible RTTY Assembly



Unless you have specific reasons to alter the LED order, however, you should stay with the stock arrangement.

3. Recommended Assembly Order

- ☐ J1, DC power jack. Ensure that it is flush with the rear edge of the PCB and that it is square with the edge. Insert the power plug as an alignment tool. Fill the holes with solder, as the solder pads are necessary for mechanical support. You may find it useful to hold J1 in place with a spring clothespin whilst soldering the first lead.
- ☐ C9, 0.1uF identified as 104
- ☐ L1, 47uH, identified as yellow-violet-black. If you have any doubt about the identify of this part, its resistance should measure in the range 1.5 to 2Ω
- ☐ C1 and C2, 0.1uF, identified as 104.
- ☐ D1 may be any of 1N4001…1N4007, or other power diode. Observe the polarity markings.
- ☐ F1, the polyfuse, ID as XF010. Carefully form the leads so that the body of the polyfuse is a small distance (1/8" or 3mm) above the PCB surface. You will find it easier to install if you carefully remove the kink in the leads.
- ☐ U4, 78L05. Note the orientation of U4 must match the PCB outline. It will be necessary to reform U4's leads to match the hole spacing.



☐ Apply +12V to J1, center pin positive. Check the output of U4 (may be measured at U2 Pin 7. It should read 5V ±0.2V. It will be convenient for this and later measurements to install a ground lead through one of the via holes. Use a cut-off lead for this purpose. After verifying the voltage, remove the power connection.

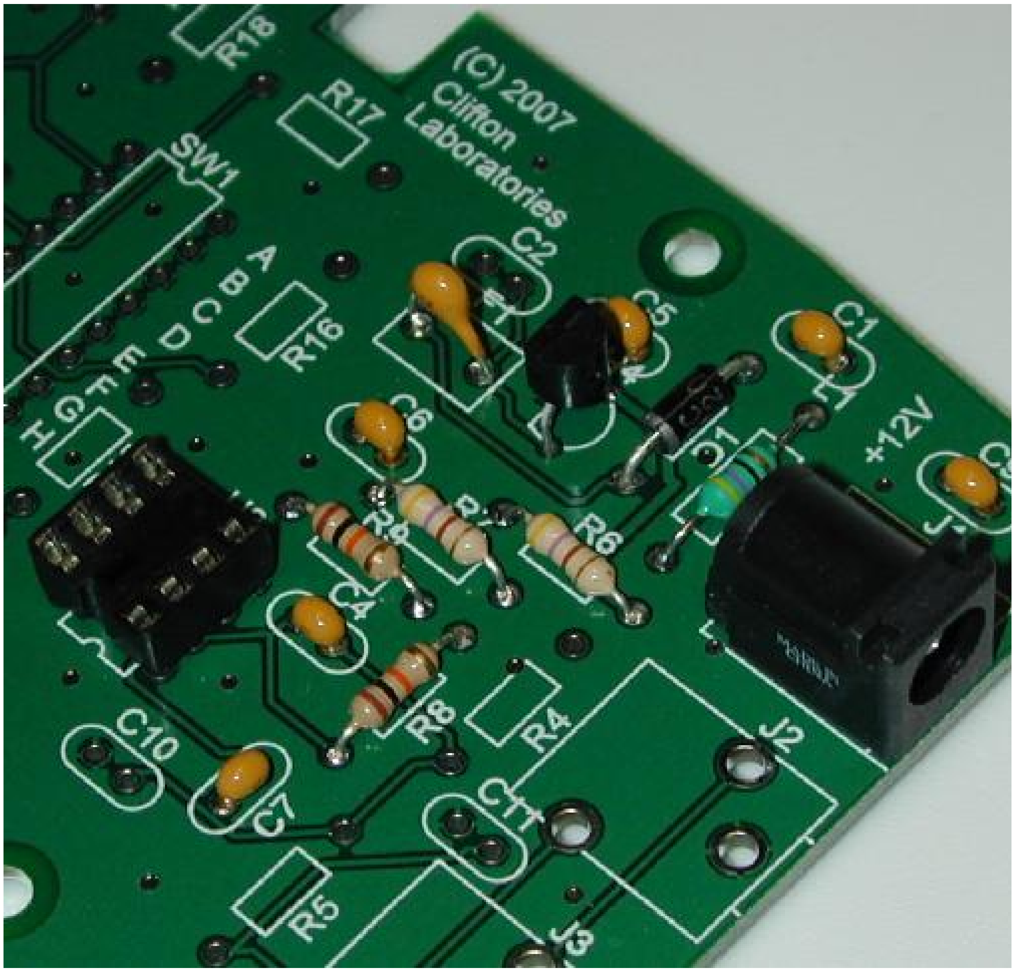
☐ R6 & R7, 470 ohm resistors identified as yellow-violet-brown.

☐ C5 & C6, 0.1uF capacitors, identified as 104.

☐ R8 & R9, 10K resistors, identified as brown-black-orange

☐ C4 & C7, 0.1uF capacitors, identified as 104.

☐ Install an 8-pin DIP socket at U2's position. Note the socket orientation -- its notch should match the notch on the PCB silk screen.



- ☐ Reapply +12V to J1, center pin positive. Check for the following voltages. All are ±5%
  U2 socket, Pin 7, should be 5V
  U2 socket, Pin 2, should be 2.5V
  U2 socket, Pin 3, should be 2.5V
  All other U2 pins should read zero volts.

  Remove power. If these tests are not passed, locate and correct the problem before proceeding.

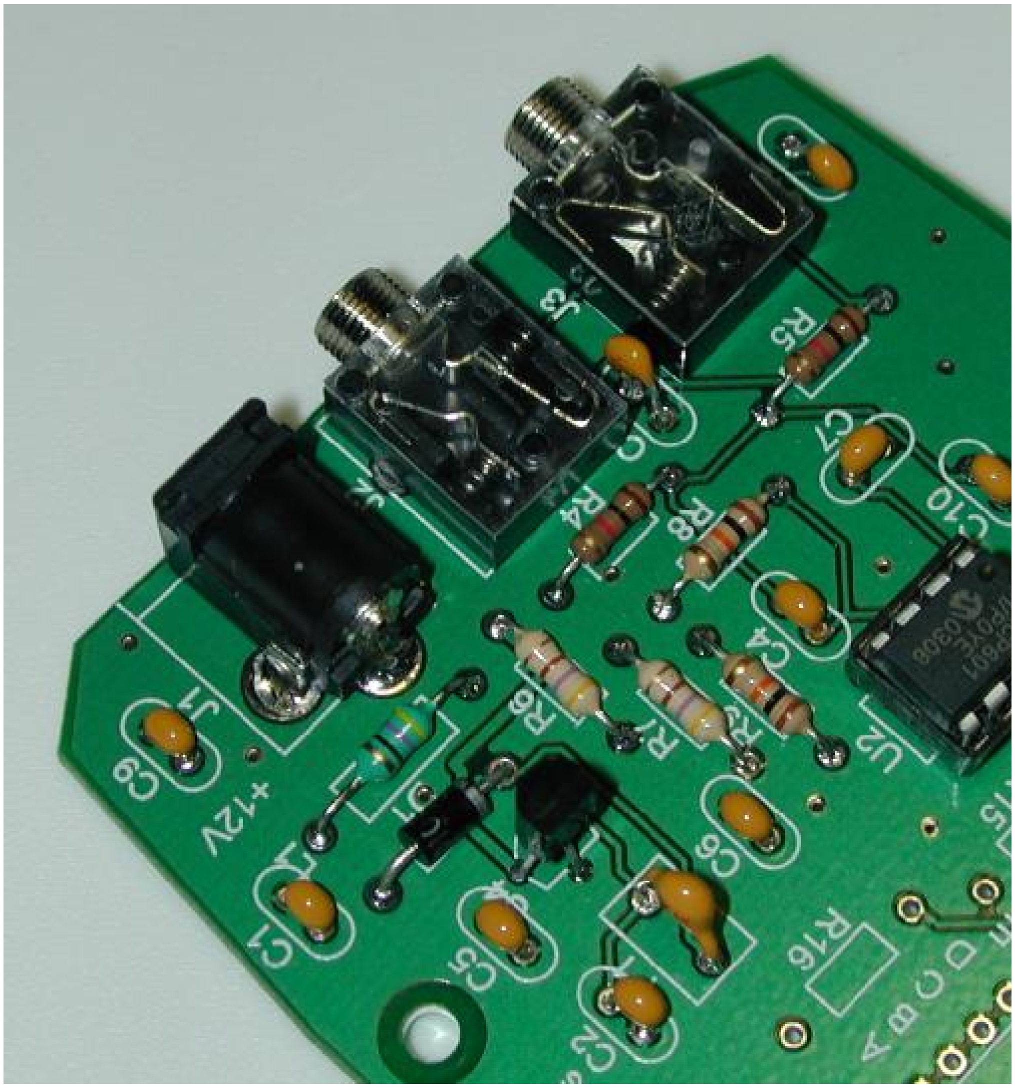
- ☐ Install C10, C11 & C12, 1000 pF capacitors, identified as 102.

- ☐ Install R4 & R5, 1K ohm resistors, identified as brown-black-red.

- ☐ Install J2 and J3, the 3.5mm stereo jacks. To assure alignment with the case holes, make sure the jacks are square with the rear board edge. For optimum alignment, solder one pin and then check the alignment, gently twisting the connector body if necessary. Solder the remaining pins in place, applying a filet of solder around 360 degrees of the pins, to provide better mechanical support for these parts. You may find it useful to hold the jacks in place with a spring clothespin whilst soldering the first lead.

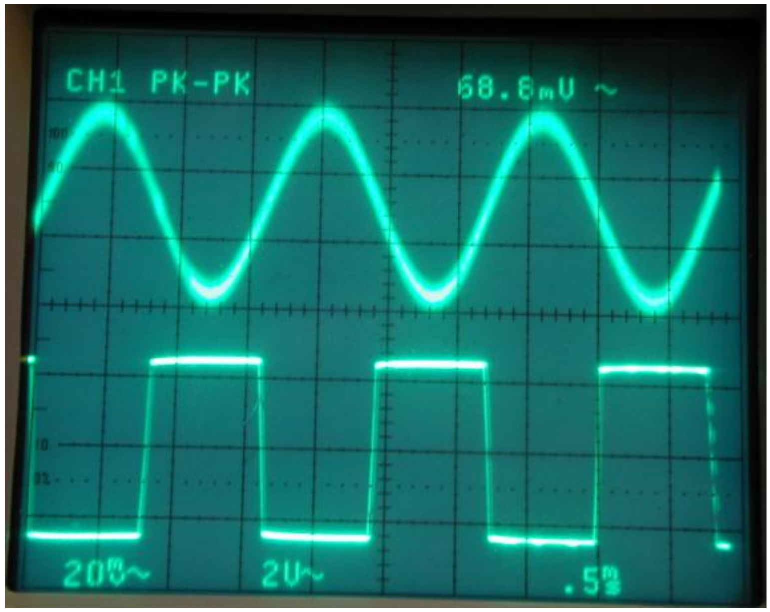
  The supplied nuts for J2 and J3 are not used and may be discarded.

☐ Install U2, an MCP601, noting the orientation.

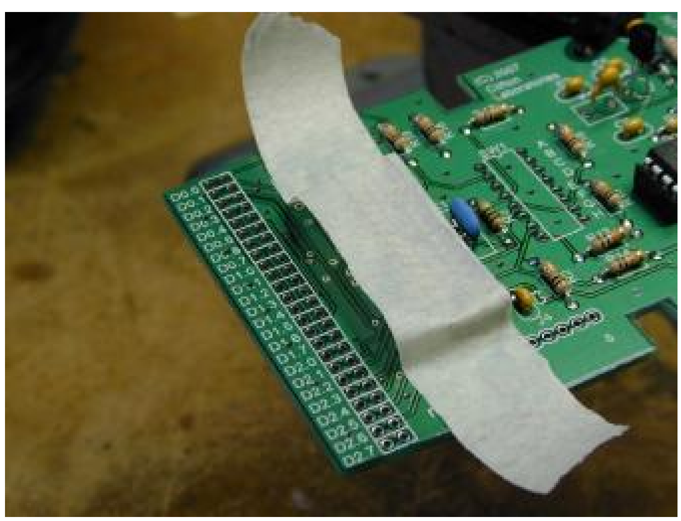


If you have an audio signal generator and oscilloscope, it is possible to check the limiter stage for correct operation. Set the signal generator for approximately 1 KHz and an output level of about 100 mV RMS. Neither of these values are particular critical.

☐ Apply +12V to J1 and the signal generator between the tip and sleeve, J2 or J3. Connect the oscilloscope to U2 (MCP601), pin 6 and you should see the following. The top channel is the applied 1000 Hz signal and the bottom channel is U2, Pin 6. The output should be a relatively clean square wave swinging between 0 and 5V, and it should be in full limiting with an applied 1000 Hz level of 25 mV RMS (70 mV P-P) or less.



- ☐ Install C3 & C8, 0.1uF capacitors, identified as 104.
- ☐ Install R2, R13, R14, R15, R16, R17, R18 & R19, all 10K resistors, identified as brown-black-orange.
- ☐ Install R3, a 1 Meg resistor, identified as brown-black-green.
- ☐ Install X1, a 10 MHz resonator. This is a 3-lead oval shaped device identified with various markings, e.g., 10M, 10MEG, 10MZ, etc.
- ☐ Install the 28 pin socket at U1. You may find it helpful to hold the socket in place with masking tape whilst soldering the first few pins. Orient the socket's notch to match the silk screen outline's notch.



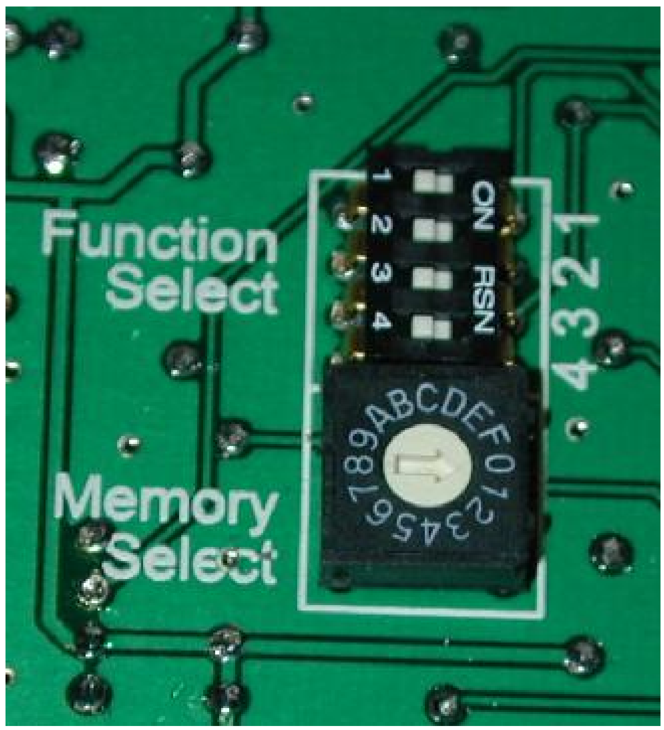
- ☐ Install the 6 position header at J4.

☐ Note—the next three components are installed on the BOTTOM of the PCB. Install R1, the 5K potentiometer on the BOTTOM of the PCB, soldering from the top. (Masking tape works well here as well to hold the part in place while soldering.)

Following the instructions below, install two switches on the BOTTOM side of the PCB following the orientation shown below. The Function Select switch has four independent slide switches. The Memory Select switch is a 16-position rotary switch.

☐ The spacing is tight between these two switches and the rotary switch may have molding flash that prevents the slide switch from squarely seating. If so, trim it off with an X-Acto knife or similar tool. If necessary, the slide switch can be mounted at a slight angle.

Trial fit both switches to the PCB.



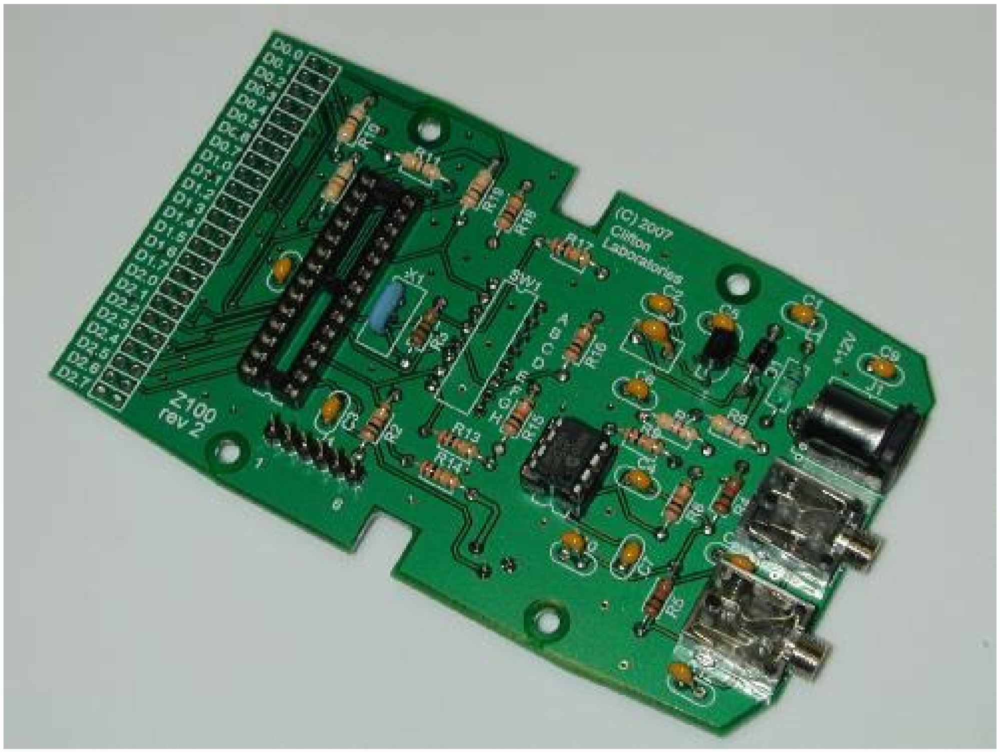
☐ Locate the 16 position rotary DIP-switch. Note that one side of the switch has four pins whilst the other side has only one pin. When the switch is oriented properly, it will match the above photo—the side of the switch with numbers 7 and 8 will be toward the Memory Select silk screen text.

Solder the pads from the top of the PCB.

☐ Install the four position DIP slide switch next to the rotary switch, also on the BOTTOM layer. The DIP slide switch occupies positions ABCD.

Orient the switch so that the side labeled ON is oriented toward the number 1…4 silk screened onto the PCB. Solder the pads from the top of the PCB. This switch may be a snug fit against the rotary DIP switch.

☐ Install R10, R11 & R12, 43 ohm resistors, yellow-orange-black. (These resistors are on the top of the board, near the 28-pin socket.)



At this point, the only electronic parts remaining to be installed are 18 red LEDs, 2 green LEDs and 4 yellow LEDs and the PIC Microcontroller, U1. If you use flux remover to clean assembled PCBs, please do so now, as flux remover should not be used once the diode shims are in place. Note that J2 & J3 (the 3.5mm audio input/output jacks) are not sealed and may be discolored by flux remover.

The effort that you put into properly installing the diodes and the shim/baffles directly affects how uniform they appear when the Z100 is assembled.

You may also wish to blacken the front PCB edge with a "magic marker" or flat black paint, as it will make the PCB edge less visible through the front lens.

Before starting LED assembly, locate the two pieces of shim/baffle stock. Using an LED as a size gauge, mark the LED's height on each end of each strip. Using a straight edge and sharp X-Acto knife, trim the two strips to match the LED height. It is much easier to trim the stock now, rather than trying to cut it to size once in place.

Each diode has a <u>long</u> (+ or anode) and <u>short</u> (- or cathode) lead and the leads must be formed as shown below. You may wish to form all leads at once, or do them individually before installation.

Bend the LONG lead at illustrated. The angle is slightly greater than 90 degrees.

Bend the remaining lead to be parallel to the first, spacing the two leads being 0.10 inches (2.5mm) apart. Both leads will be at the same angle.

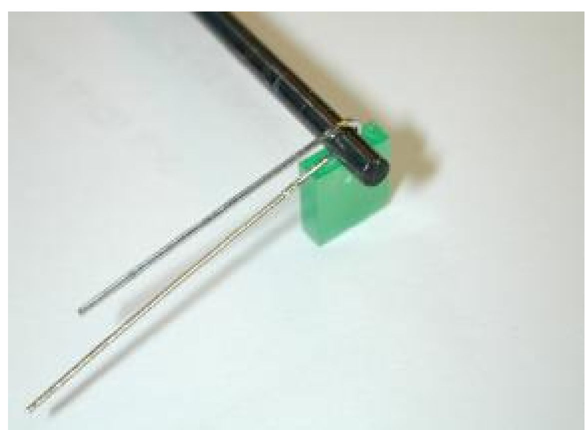
The purpose behind bending the leads more than 90 degrees is to allow the LED's front to be closer to flush with the PCB edge.

Mike, W2PY, provides a description of how he bent the LED leads:

"I laid each LED down on the desk and with the LED body to the left and the leads to the right with the longer lead towards me. Using a small flat blade screwdriver between the two leads I slowly turned the screwdriver clockwise while pressing the blade tightly to the LED body. That way I got a nice tight bend in the lead, tight against the LED body. Then I used small needle nose pliers to space the second lead consistently and manually bent that lead with my fingers to match the angle of the first lead. This produced nearly identical bends on all of the LEDs."

I usually use my fingers to make the bend as it's easier to control the angle.

To bend the short lead, form it around a drill bit shank approximately 0.100" diameter. A No. 38 drill is 0.101" diameter, or a 3/32" drill may be used if a #38 is not available.



This trick was suggested by VK4SQ and it works well.

If you use needle nose pliers to make the bend, you can make a pencil mark to show the bending location. (Thanks to Bruce, W8BH for this suggestion.)

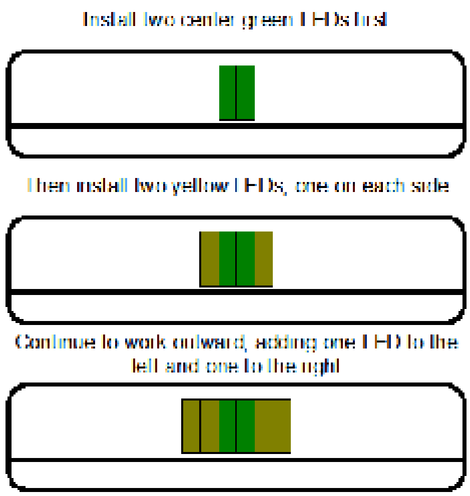
☞ **PLEASE READ THE FOLLOWING STRATEGY FOR LED INSTALLATION. IF YOU CAREFULLY FOLLOW IT, THE DIODES WILL BE PROPERLY ALIGNED AND SPACED.**

This manual contains three alternative approaches to installing the LEDs. The

one described below requires no special tools, beyond a spring clothespin and a rubber band. An alternative approach, developed by Mike, W2PY, is described at the end of this manual, following the board outline drawing. His technique requires a small modeler's bar clamp and can yield excellent results. A third method, developed by Bruce, W8BH, also requires no special tools, and is described at the end of the manual, following Mike's methodology.

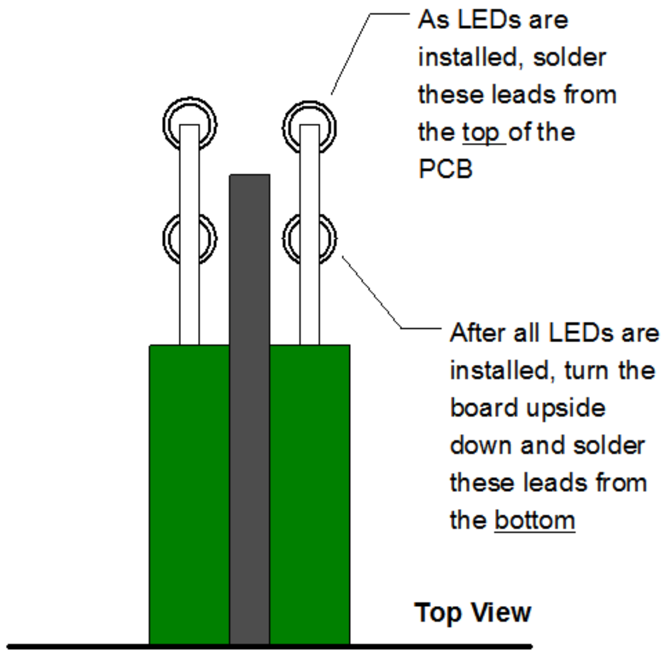
Before installing the LEDs, locate a small rubber band and a spring clothespin. These will be used to hold the diodes in place.

The trick to installing the diodes is to start at the center with the two green LEDs and work outwards in both directions simultaneously, installing one diode on each side and then soldering them in place.



After inserting a diode, take time to orient and align it. The diode face should be parallel to the PCB board and the front edge of the diode will have a very slight overhang from the PCB edge, not more than 0.04" (1mm) Looked at from the front, the diode should be perpendicular to the board and looked at from the side the diode should be flush against the board for the entire body length. <u>The front of the diode should not extend beyond the PCB's edge beyond the minimum necessary distance</u>.

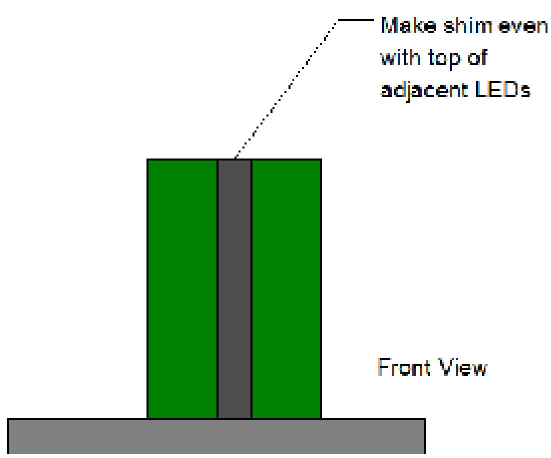
When the diode is properly aligned, solder the rear lead. I find this process to work best if the PCB is held in an assembly vise, soldering the rear lead from the <u>top of the PCB</u>, not the bottom. This requires a small tip on your soldering iron. If you adopt this approach, the plan is to solder the rear lead of each diode as it is installed, flipping the PCB upside-down and solder the front leads from the bottom, but only <u>after</u> all diodes are in place.

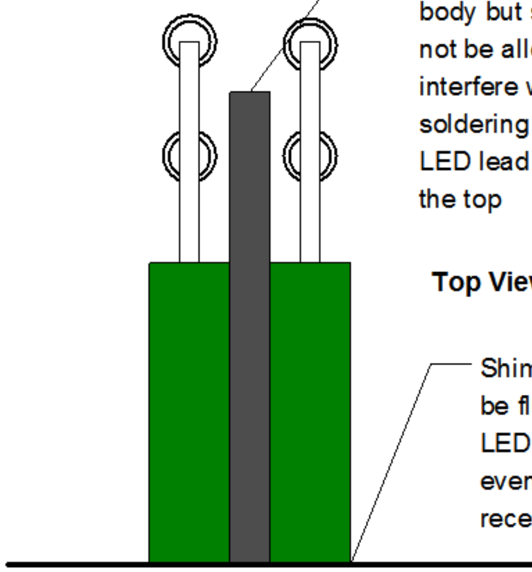


The diodes are spaced 0.100 inches (2.54mm). The diode bodies are 0.091 inches wide (2.3mm) and a strip of paper or plastic shim stock, approximately 0.009" (0.2mm) is provided to separate and align the diodes during assembly.

These shims provide a second purpose; they act as a baffle to prevent the light from one LED from being coupled into the adjacent LEDs, thus giving the appearance of several LEDs being illuminated at once, instead of one.

Since the shims will be retained after construction, it is important that the shim material be carefully trimmed and cut as illustrated below.





Normal typing or copy paper is only 0.003" (0.08mm) thick, so please use the provided material. The shims should be cut to size as illustrated above. The length of the shim is not as important as its height, but the shim should not be so long as to interfere with soldering the back lead from the top.

Using two LEDs as guides, mark each end of a length of shim stock to show the height of the LEDs when installed in the Z100's orientation. (Or, you may measure the lines. The LEDs are 0.276" (7 mm) tall and 0.312" deep (8 mm). The ideal shim size is thus 7 mm x 8 mm, but if you are to make an error, it should be on the large side of these dimensions.)

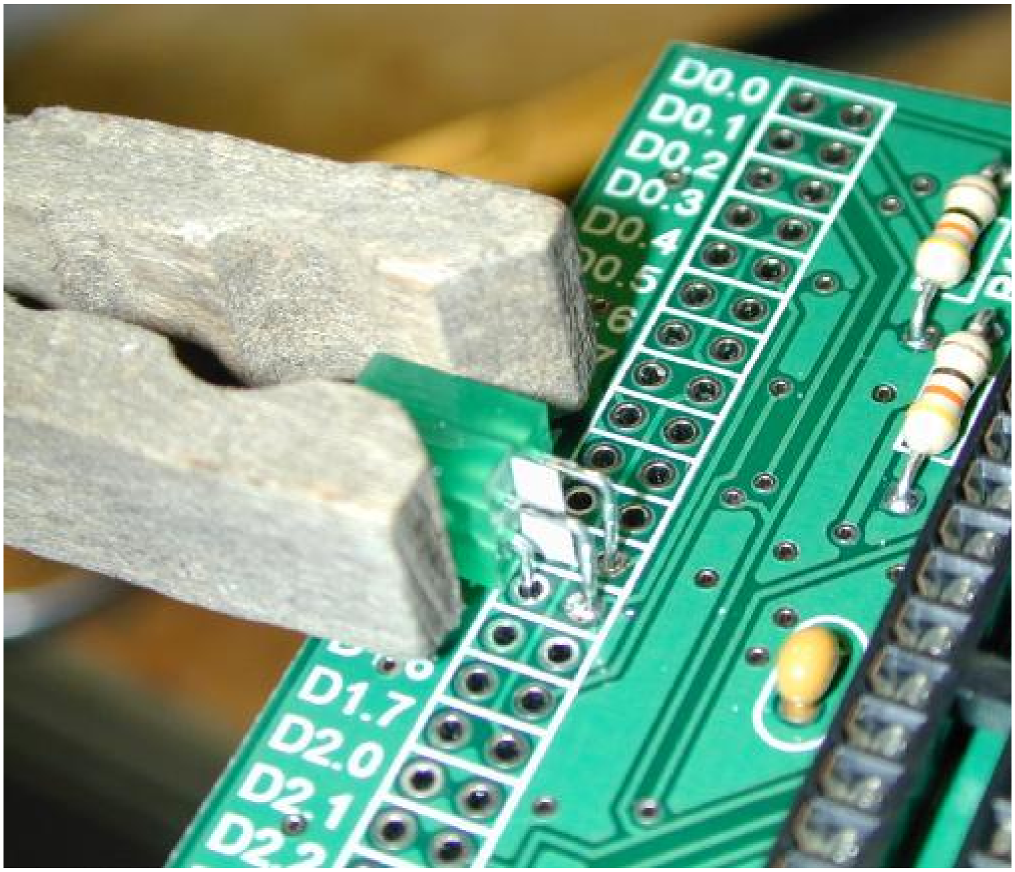
Using a straight edge and sharp X-Acto knife, cut the shim stock to this height. A sharp blade will not leave fuzz after the cut. Repeat for the second shim stock strip. As you need a piece of shim stock, cut it from the trimmed strip.

This procedure works much better than trying to trim the shims once in place between diodes.

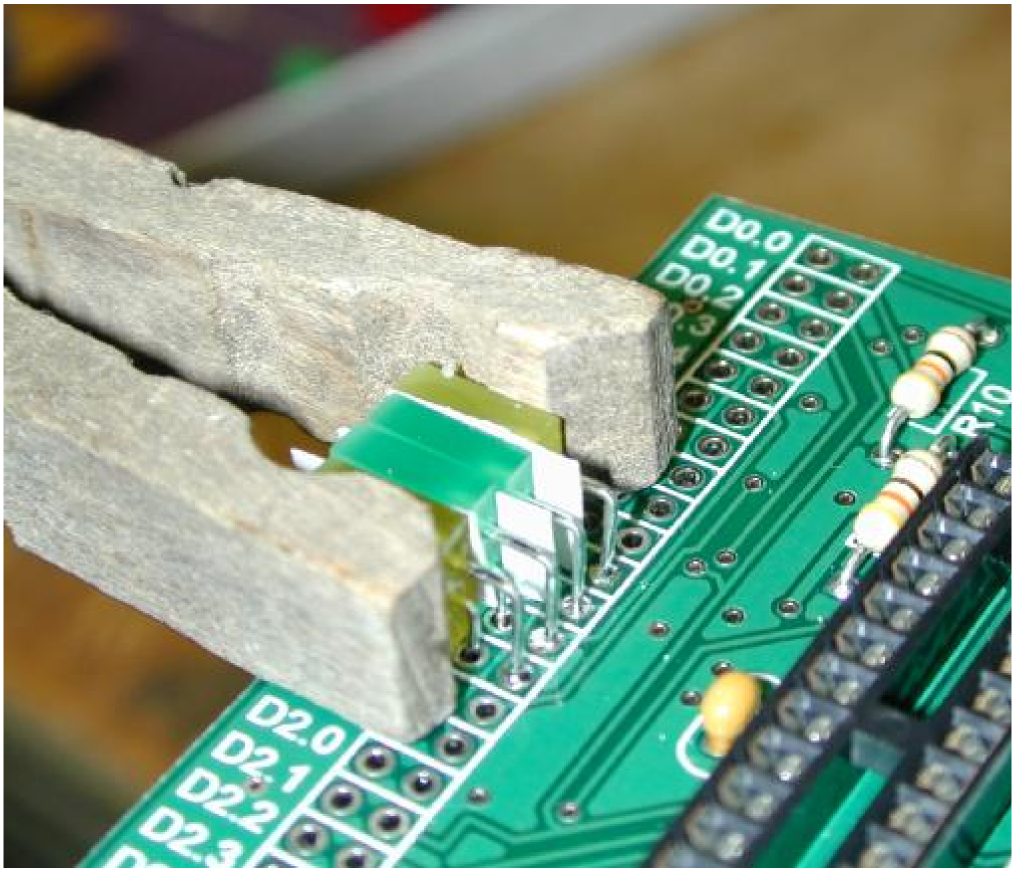
Before installing the first diode, please read the full LED assembly process.

Place, but do not yet solder green LEDs at positions D1.3 and D1.4. It's critical that you start in the correct position, so as a double check, count the number of empty spaces for diodes on either side of the two green LEDs. There should be 11 empty spaces on each side.

☐ From the trimmed shim stock, cut a small strip and insert it between the two green diodes to space them. Hold the two diodes in place with a spring clothespin. Recheck the diode alignment to be square with the PCB and as close to flush with the PCB end as is possible. Solder the back leads of each diode from the top. Don't worry if the shim material is not exactly aligned, as you can touch up the shim positions after all diodes are soldered in place.



☐ Install two yellow diodes, one at D1.2 and D1.5. Cut two shim strips to properly space these diodes. Align the diodes and clamp with the spring clothespin. When placed and aligned, solder the back leads of these two diodes, soldering from the top of the PCB.



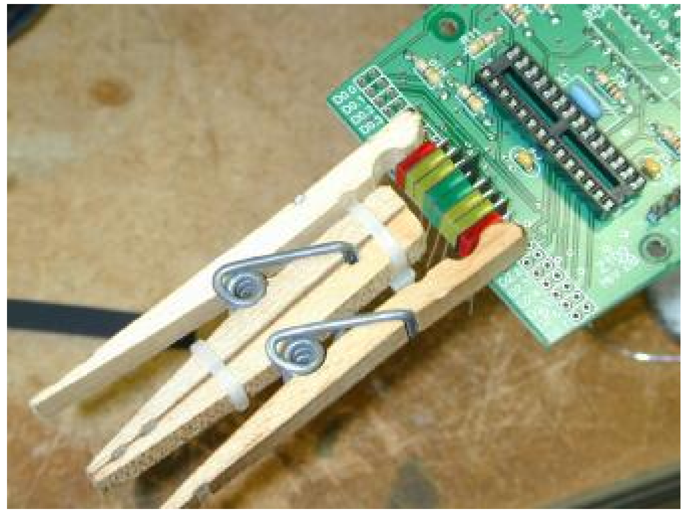
Repeat this process, adding one yellow diode on each side of the yellow LEDs just installed, using shim paper for spacing. At this point, the arrangement will be (looking from the front) [Y][Y][G][G][Y][Y]. All remaining LEDs are red.

☐

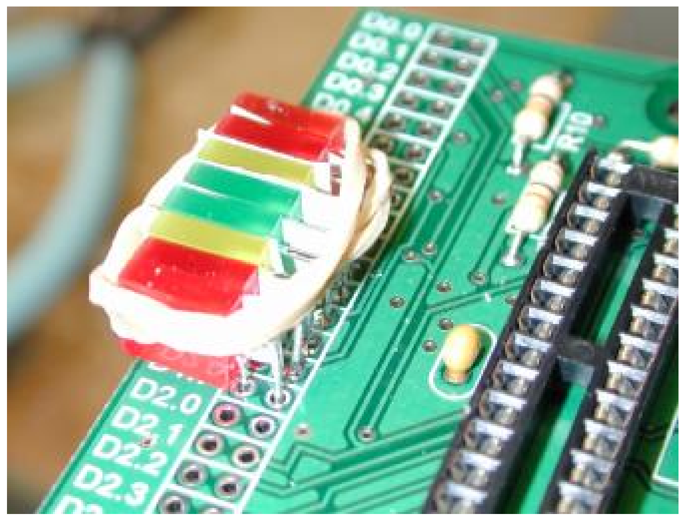
The spring clothespin will not expand to hold more than four diodes, so use a small rubber band to hold the diodes in place.

(One of the photos below uses only two yellow LEDs; your kit uses four yellow LEDs, two on either side of the two green LEDs.)

I made a "double clothespin clamp" to hold LEDs in place. This works only up to about 16 LEDs. After that point, you have to use rubber bands or another approach.



Or, you can use rubber bands to hold the LEDs in place after you install the first six LEDs.

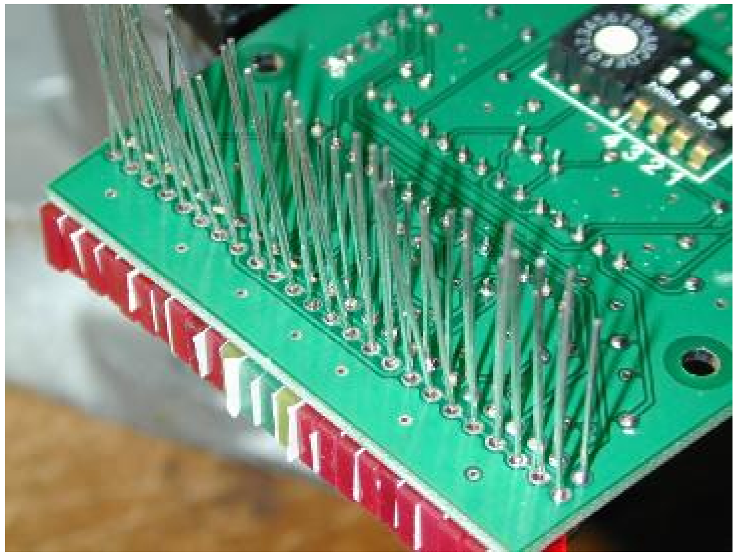


If you have a small modeler's bar clamp, as suggested by W2PY, use it.

It provides an adjustable clamping force and the bar also serves as an alignment guide for the diode front surface.

☐ Using the same technique, install the rest of the diodes, using shims to keep the diodes uniformly spaced.

☐ Working carefully not to disturb the diode alignment, flip the PCB upside down and solder the front diode leads in place. Starting at one end, solder the front diode lead in place and clip the front and back lead. Then repeat the process. It is not necessary to solder the back lead a second time, as the top soldering is adequate.



☐ Check the shim alignment. If necessary gently align any out-of-position LEDs. Shims that protrude past the front end of the diode or stick out above the LED top will be visible when your Z100 is assembled and will detract from its appearance. If necessary, with a razor blade or X-Acto knife, trim the shim material for best appearance.

☐ Dave, G3TJP, notes that if you view the Z100 from slightly above, light leakage from the LED's top causes the display to appear "feathered." To avoid this, cut a length of black electrical tape about 3/8" (10mm) wide and stick it on top of the LEDs, and down the side of the outer LEDs. This ensures that the only thing visible through the lens are the LED front faces.

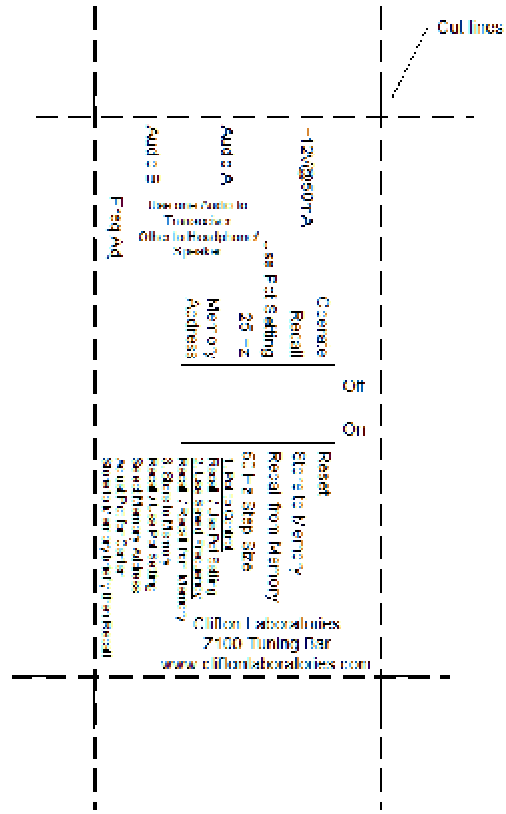
☐ At the point, electronic assembly is complete.

☐ Set all rocker dip switches to OFF. Set the rotary memory switch to position 0. Mount U1 in the 28-pin socket, orienting U1's notch to match the silk screen notch. You will likely find it necessary to bend U1's pins to fit into the socket. This may be done by pressing U1 against a hard smooth surface, such as a table top, oriented so that the pins contact the table top. Repeat for the other side.

Apply +12V power and you should see the Z100's self-test operation—upon power on, each LED is sequentially illuminated, from left to right. If this self-test is passed, proceed to the next steps.

☐ Using an X-Acto knife, cut the label to size.

The label has four crop marks. Use the crop marks as cutting guides.



Next, attach the trimmed condensed instruction label to the bottom enclosure half using the following procedure.

First, with the protective backing still attached, see how the label fits to the enclosure bottom. Hold the bottom to a bright light and align the rectangular outline with the enclosure's opening. Holding the label in place, make alignment marks with a pencil on the enclosure. You may also wish to clean the enclosure's bottom surface with a mild solvent, such as denatured alcohol (methylated spirits) to improve the label's adhesion.

☐ Remove the label's protective coating and apply it, aligning the label with the pencil marks you have just made. It is best to let the label make very light contact with the enclosure bottom as you may need to slightly reposition it for exact alignment. When aligned, press the label in place.

Using a sharp X-Acto knife, cut the label to correspond with the switch access opening and the center frequency potentiometer access opening. A dull blade will leave fuzz on the cut edge.

The enclosure bottom will look like the following photograph at this point. (Yes, I used a dull blade and the cut edge is fuzzy!)

The Z100 is supplied with a piece of 35% light transmission neutral gray film. The purpose of the film is to increase the LED contrast, at which it is quite effective. However, properly installing the film can be tricky and you may decide to operate the Z100 without the film in place.

I have found two slightly different ways to install the film, and you may find an even better approach. The Z100's I have built for my personal use follow Option B, as do "assembled and tested" Z100s. If you find that one approach does not work for you, try the other. There's enough gray film provided for you to try both options.

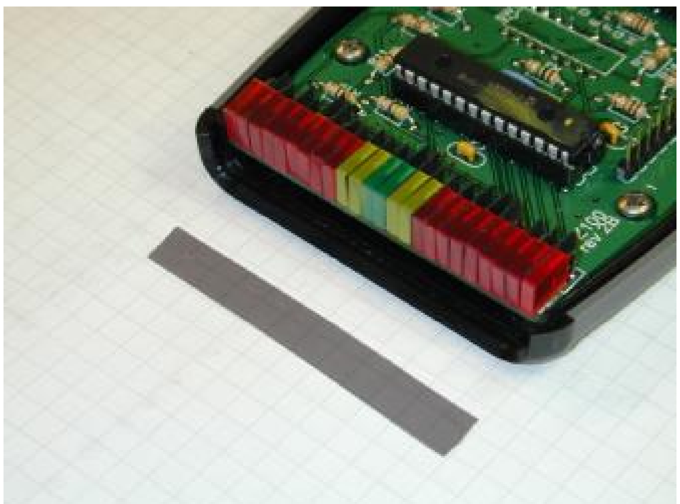
Option A is the simplest method, but does not mask the PCB from outside view. Option B, which covers the entire lens, provides better results, but is more difficult to do.

☐ Before working with the film with either option, first place the PCB in the lower enclosure half and examine the clearance between the front of the LEDs and the lens. Trial fit the lens (do not remove the protective covering yet) and verify that there is no interference between the LEDs and the lens surface. If there is, gently reform any protruding LEDs. Ideally, there will be sufficient clearance between the back surface of the lens and the front LED surface to slip a business card between the two. However, normal tolerances make that clearance impossible to achieve in all cases. However, your Z100 will work as long as there is minimal clearance between the LEDs and the lens. Remove the PCB from the enclosure half after completing the trial fit.

<u>Option A</u>

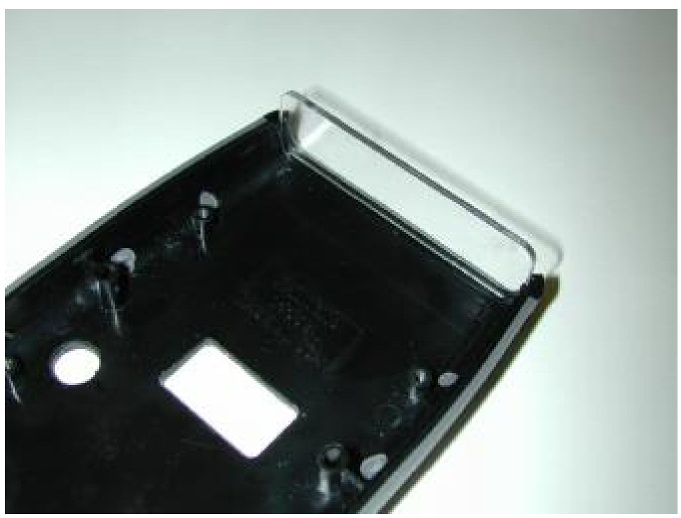
☐ Using a straight edge and a sharp X-Acto knife, cut a strip of film equal in height to the LED height and slightly longer than the LED assembly (the LED assembly is approximately 2.4 inches, so cut the film to 2.5 inches.). Use a sharp blade with minimal pressure. It may take six or more passes to cut through the film, but the result will be a smooth edge, without tears.

Note: The two following photographs show the PCB installed in the lower enclosure half. At this point your PCB should <u>NOT</u> be installed in the lower enclosure half.



☐ Place the film on the front of the LED string and burnish it in place with your fingers. The film will cling to the LEDs and does not require adhesive or tape to hold it in place. Make sure that the film does not extend past the edges of the outside LEDs. Since the film was intentionally cut a bit long, trim it to the correct length.

☐ Remove the protective covering from the lens (both sides) and snap it into place in the bottom enclosure half. (Remember—at this point, the PCB should not be in the lower enclosure half.) The lens may be a tight fit and you may need to apply force to it. If so, you will hear a distinct "snap" when the lens is in place. The lens is symmetrical so either side may face outward. To verify that the lens is correctly seated, trial fit the enclosure top half, holding the two enclosure halves together with a rubber band. It may be necessary to apply pressure to the top half as well, again until you hear a "snap." Remove the top enclosure half.



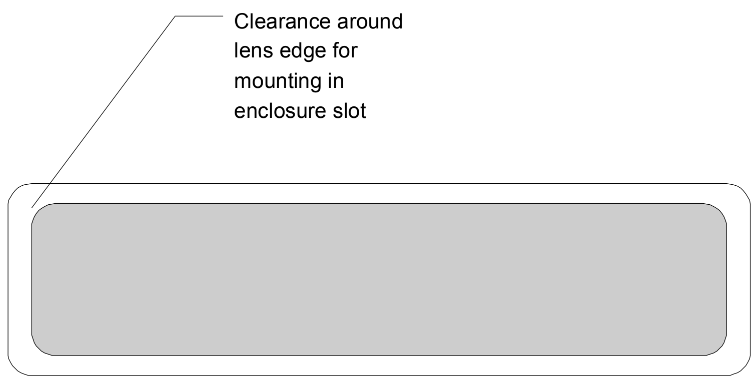
☐ Now insert the PCB into the lower enclosure half, with the lens in place. Angle the PCB into place so that the film over the LEDs is not shifted or displaced during the assembly.

Install the four 4-40 x ¼" machine screws to hold the PCB in place. Although the bosses have holes, they are not tapped. However, the case is formed from soft plastic and the machine screws will tap their own threads when installed the first time. Check the shims and return any that may have shifted to the correct position.

Option B:

Option B intentionally attaches the gray film to the lens. For this to work there must be sufficient space between the front of the LEDs and the back of the lens (including film thickness) so that the LEDs do not touch the film. This may not be possible in all Z100 assemblies, due to spacing tolerance and how you installed the LEDs. If the LEDs touch the film, the result will be similar to a bubble; it will work but appearance will be mottled. It will also be extremely difficult to install the case and lens as any LEDs contacting the film will push it out of place during assembly.

Option B's concept is to apply the film to the lens, cutting the film undersize so that it does not interfere with the case's lens mounting slot. The lens itself is a tight fit into the slot and the lens plus film will not fit. Hence, it's necessary to trim the film around all four edges to allow the lens to fit into the mounting slot.



The following procedure will help you get the film trimmed to the correct size.

With the PCB not installed, assemble the lens in the enclosure.

(It is not necessary to use the two case screws—you can hold the case together with your hand.)

With a fine tip marker, trace around the enclosure's edge, marking on the lens's protective film. Make sure the top and bottom enclosure halves are firmly together.

Remove the protective film and trim the film around the line.

Use the trimmed protective film as a template for cutting the neutral gray film.

Note: When trimming the film in the following step, you will obtain the best results with a new sharp X-Acto knife. Don't apply pressure during cutting; let the knife's sharpness do the cutting. Make several passes to cut the film, with gentle force.

Place the protective film template on top of the gray film. Smooth it in place—it will cling due to static electricity.

Using a sharp X-Acto knife and a straight-edge, trim around lines—apply gentle pressure with multiple passes to avoid dragging the film or tearing it.

I recommend cutting the neutral gray film a bit smaller than the template.

After you have trimmed the neutral gray film, remove the protective film from the other side of the lens.

Lightly spray one side of the lens with water, or a glass cleaning product, such as Windex. Place the film on the lens, centering it so that the clear space is identical on all four sides. Using a roller, or piece of flexible plastic (such as a credit card) gently smooth the film so that when viewed from the opposite side you see no bubbles.

Snap the lens/film assembly into place in the bottom enclosure half (film to the inside). The lens may be a tight fit and you may need to apply force to it. You may hear a distinct "snap" when the lens is in place. The lens is symmetrical so either long edge may be place up. Check to see if the film has been displaced or pushed up and wrinkled. If so, you may have inadequate clearance and the film will require further trimming.

To verify that the lens is correctly seated, trial fit the enclosure top half, holding the two enclosure halves together with a rubber band. It may be necessary to apply pressure to the top half as well, again until you hear a "snap." Remove the top enclosure half and verify that the film has not been displaced or wrinkled.

The film will stay in place without adhesive if properly applied using this process.

When you have the lens/film assembly in place without wrinkles or bubbles, install the assembled PCB. Take care that the gray film does not shift from inadvertent contact with the PCB or the LEDs as you install the PCB.

Install the four 4-40 x ¼" machine screws to hold the PCB in place. Although the bosses have holes, they are not tapped. For a higher quality job, you may wish to tap the holes with a 4-40 bottoming tap. Check the shims and return any that may have shifted to the correct position.

Finishing the Assembly After Option A or Option B

☐ Install the top case half, securing it in place with the two long black self-tap screws.

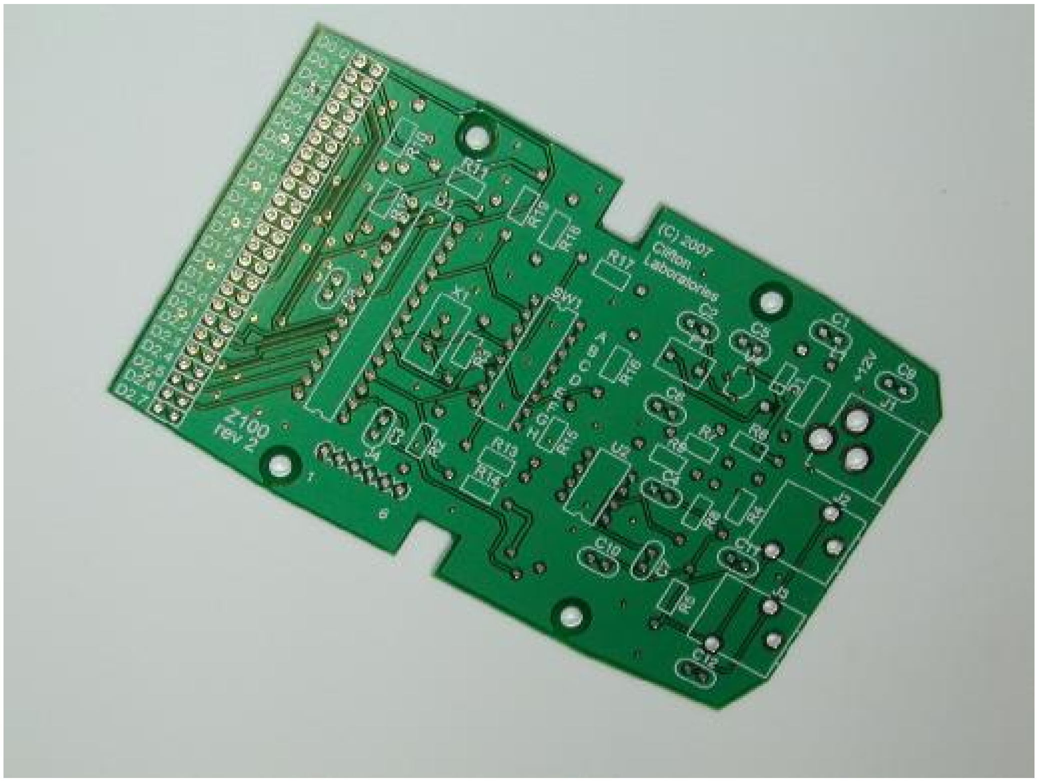
☐ Attach adhesive rubber bumpers to the four corners of the lower enclosure half.

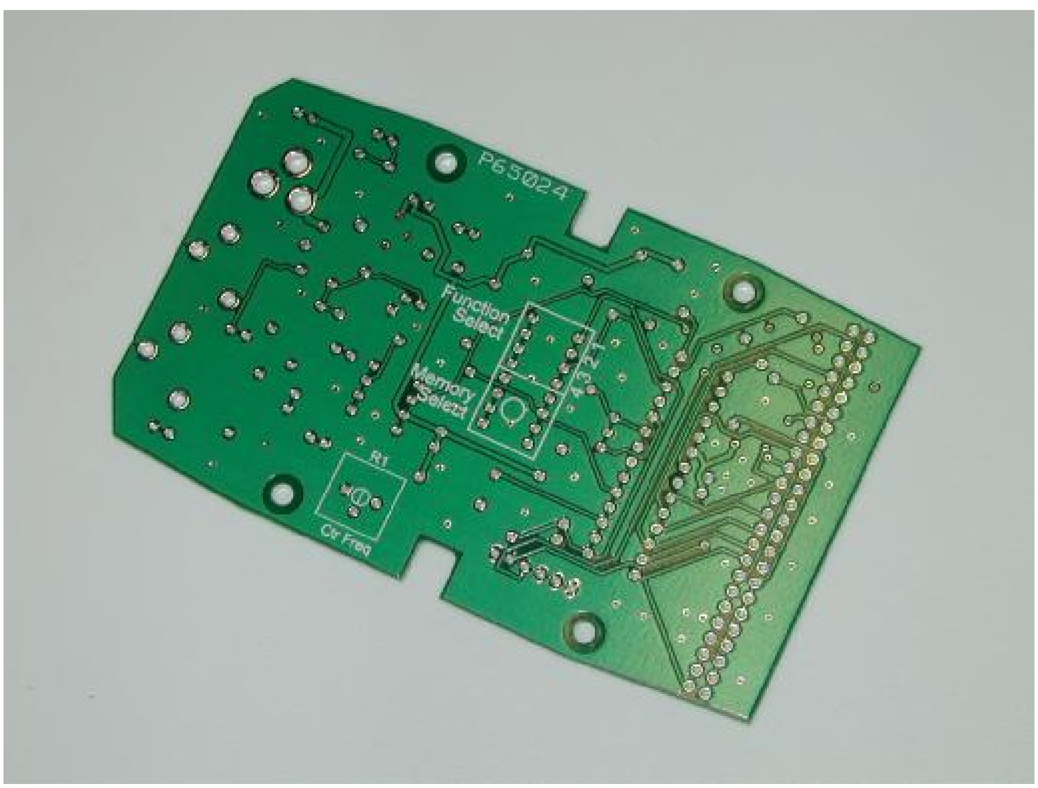
NOTE: The default slide switch positions are all OFF. This sets the Z100 into potentiometer frequency control mode.

You can either adjust the frequency control potentiometer to match your side tone frequency or use one of the stored frequencies.

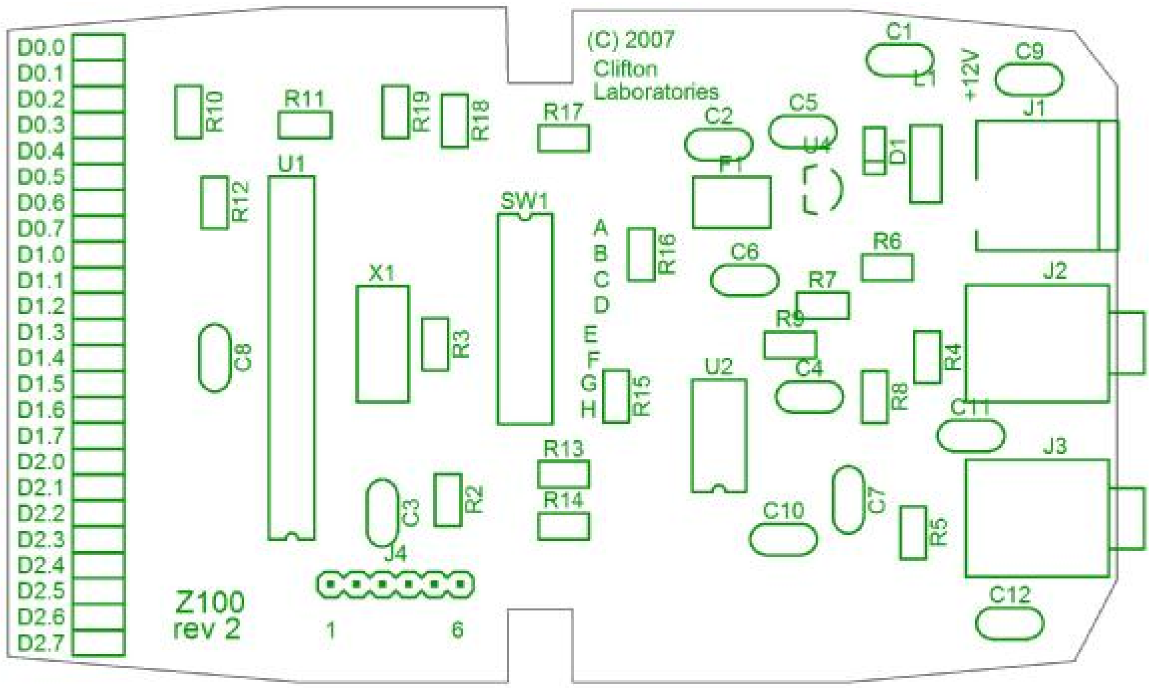
Please refer to Pages 6-8 of this Operating Manual for more details on adjusting your Z100's frequency to match your CW side tone.

Board Photographs





Board Component Outline Top Only



Alternative LED Assembly Instructions

<u>Alternative 1</u>
Mike, W2PY, has provided photographs and text showing how he assembled the LED section of his Z100. Mike has made excellent suggestions that will be incorporated in the next manual revision.

The more care you take with the LED alignment, the better the results will look. Mike's craftsmanship, as his photos demonstrate, is impeccable.

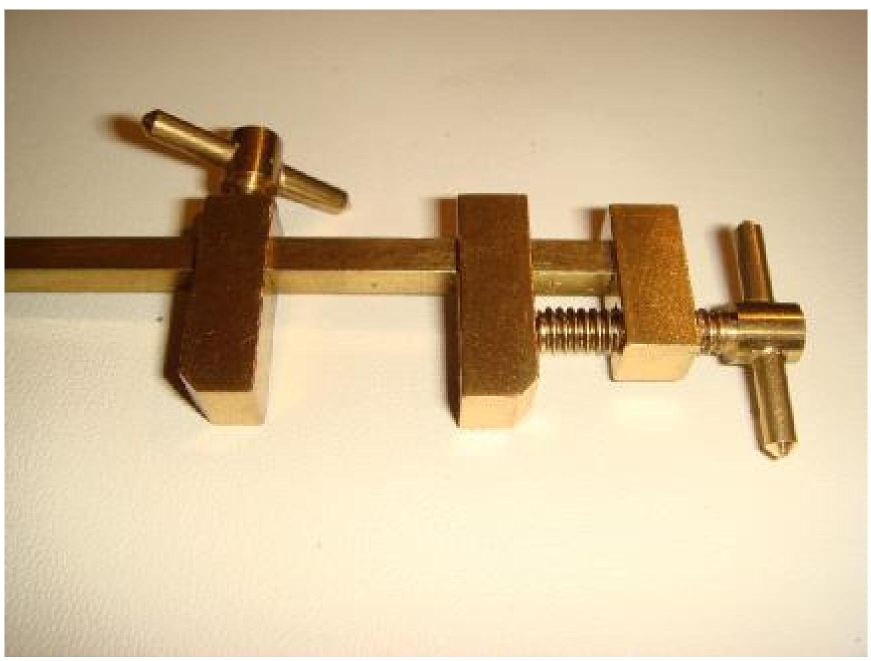
The following is Mike's description and his photographs.

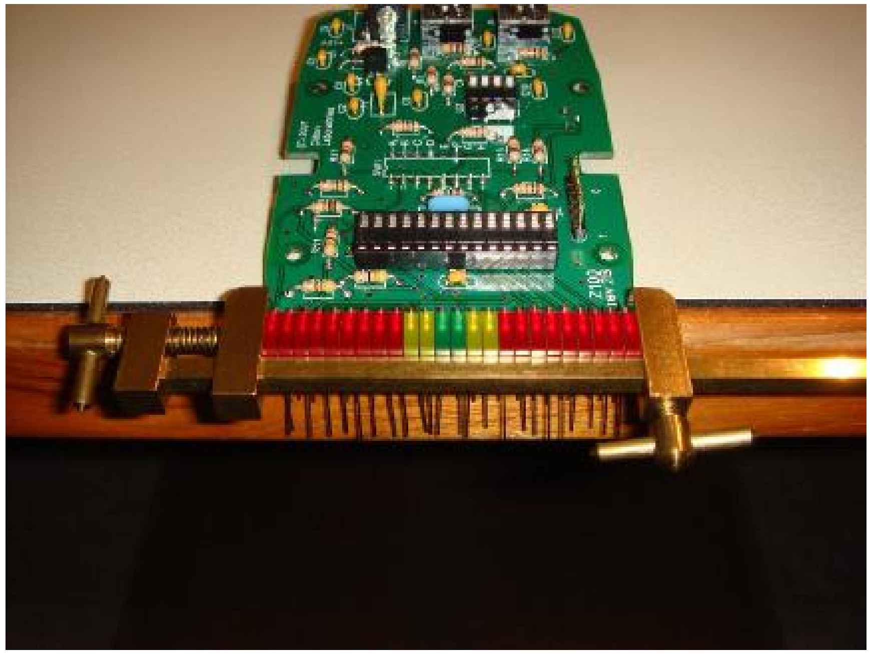
1. I bent all the LED leads. I laid each LED down on the desk and with the LED body to the left and the leads to the right with the longer lead towards me. Using a small flat blade screwdriver between the two leads I slowly turned the screwdriver clockwise while pressing the blade tightly to the LED body. That way I got a nice tight bend in the lead, tight against the LED body. Then I used small needle nose pliers to space the second lead consistently and manually bent that lead with my fingers to match the angle of the first lead. This produced nearly identical bends on all of the LEDs.

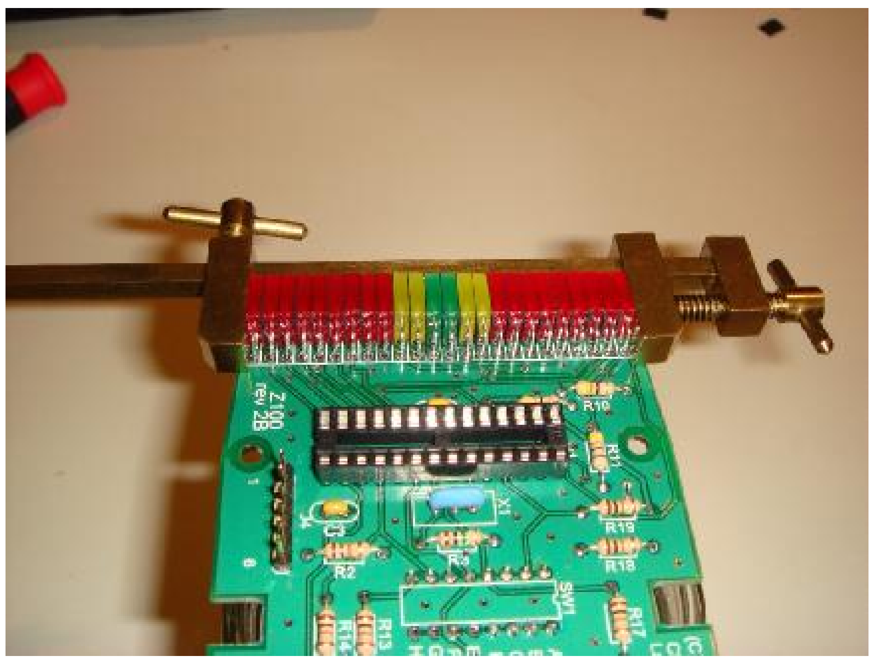
2. I inserted all of the LEDs into the circuit board.

3. I inserted the black spacers between each pair of adjacent LEDs.

4. Using a small "hobby clamp" (see photos) I clamped all of the LEDs and spacers together, but not too tightly.

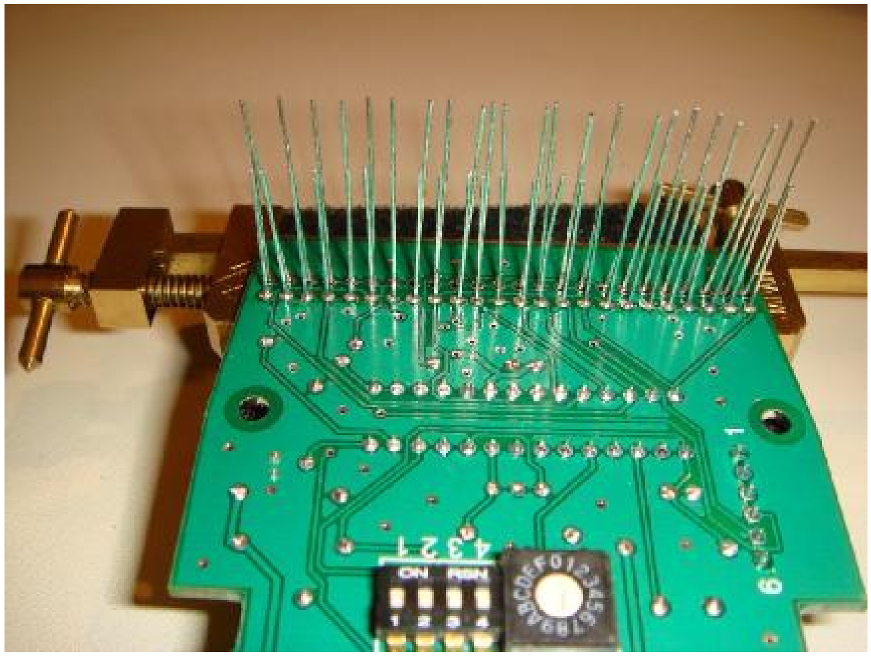


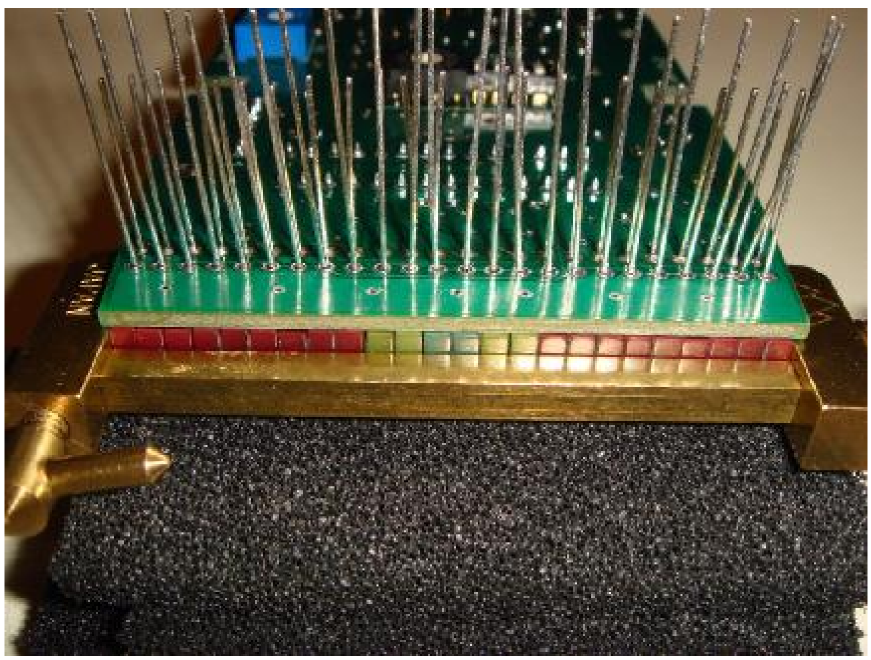




5. With all the LEDs clamped together, I used a small screwdriver to carefully align each LED down tightly against the circuit board and back against the circuit board edge. I took my time and "fiddled" with the LEDs until I was confident they were all aligned properly.

6. I soldered all of the rear leads as a group, from the bottom of the board, rechecked the alignment, and soldered all of the front leads as a group.





7. When I removed the clamp, all of the LEDs and spacers are true and flush – please take a look at the photos.

Alternative 2

Bruce, W8BH, describes his LED installation method:

> I didn't have the nice clamp that W2PY has, and I suspect that others might not either. But when you follow his instructions you really don't need any clamp. After placing the shims, turn the PCB upside down on a flat surface. This will naturally seat all the LEDs flat against the PCB. If any of them are sticking out beyond the PCB edge too far, they can be pressed inward now. (I tried adjusting the LEDs before flipping the board, and LEDs and shims went flying everywhere.)
>
> Once flipped, the side LEDs tend to spread out a little bit, but these can be pushed inward with very little pressure. I used two pieces of angle iron, but small tools or pencils (eraser end) held by books would work well, too. Then solder all the leads. No need to do any top-of-board soldering, etc.