Building and Operating:
The SMT Zerobeat kit
A PIC based CW zerobeat indicator
from Jackson Harbor Press

Ed Nisley, KE4ZNU, wrote an article published in the August, September and October of 1996 issues of Circuit Cellar magazine titled: Tuning Up. That article dealt with a project called Zerobeat - a Morse code tuning aid for ham radio operators. Zerobeat allowed the user to easily adjust their transceiver frequency to within +/- 10 Hz of another station.

This kit, called: SMT Zerobeat, is my 3rd version of Ed's original. It uses a different processor along with similar but simpler external hardware. It offers comparable performance to the original. Although imperfect, I think that experienced and new hams alike will find it a valuable addition to their shack. SMT Zerobeat has 9 LEDs that when lit, either singly or in pairs indicate how far a received carrier tone is from the ideal "zerobeat" offset frequency of the transceiver. The LEDs are lit per the following table:

blue	-150 to -170 Hz and below
blue-red	-130 to -150 Hz
red:	-110 to -130 Hz
red-red	-90 to -110 Hz
red	-70 to -90 Hz
red-amber	-50 to -70 Hz
amber	-30 to -50 Hz
amber-green	-10 to -30 Hz
green	+/- 10 Hz
green-amber	+10 to +30 Hz
amber	+30 to +50 Hz
amber-red	+50 to +70 Hz
red	+70 to +90 Hz
red-red	+90 to +110 Hz
red	+110 to +130 Hz
red-blue	+130 to +150 Hz
blue	+150 to +170 Hz and above

There is an additional LED (detector) which shows whether a code element is currently being received. A level set pot is adjusted by the operator until this LED lights in time to a received code stream. The only other additional control is an optional switch which is used to set the center or offset frequency. This setting is stored in the internal memory of the PIC microcontroller and is retained even when the power is removed. Unless otherwise instructed by the purchaser, SMT Zerobeat is preset to a center frequency of 600 Hz.

The optional switch also allows the user to reverse the indication with a switch press and release. This is NOT stored in memory and will be lost after the next power down.

Why the SMT Zerobeat ? The Grandson of Zerobeat kit will continue to be sold but the DIP components are becoming more expensive and harder to find. The SMT Zerobeat should have a longer life cycle. Also, the LEDs used in the SMT Zerobeat are brighter and also use less power than the DIP version. The SMT Zerobeat uses roughly 14 mA with three LEDs on at the same time (the maximum).

General notes on building the SMT Zerobeat:

One decision the builder should make before starting construction of SMT Zerobeat is how the project will be mounted in the case. This may be affected by how the kit is customized or modified by the user for their particular needs. A list of optional modification ideas is presented later in this document – the builder might want to check this list before proceeding with the build. None of the mods are suggested or required – it's the builders choice what to do !

In any case, the kit construction will prove to be easier if these decisions are made before soldering the LEDs and resistors to the circuit board.

Building and Operating: SMT Zerobeat from Jackson Harbor Press

A hole (or holes) in an opaque case will be needed for the LEDs supplied with the kit - I usually mark the metal case (using an awl) with a rectangle sized the same as the LED - then a series of holes are drilled within this rectangle. A flat file is then used to smooth out the opening into a rectangular shape.

While the surface mount parts used are relatively large (1206 passives, SO ICs) the builder should have some kind of magnification to see the markings and be able to inspect the soldering.

The components should be soldered in place one at a time. The pads and traces are small and delicate - a small tipped soldering iron should be used. Good quality solder wick is suggested to clean up any excess solder. A good quality tweezers can help to orient and hold the part while soldering.

Finally, the integrated circuits, U1 (PIC) and U2 (op amp), are both MOS devices. This means that they should be handled as little as possible to prevent static damage. The builder should use a grounding strap and anti-static mat if available or at the very least, work on a grounded metal surface and be sure to touch ground prior to soldering the ICs.

Building the SMT Zerobeat:

Step 1) Get the parts together: All of the board mounted components have been supplied but you will still have to provide off-board items to fully implement the kit. These items include:

J1	power connector or battery connector/holder
J2	audio input connector
SW1	momentary SPST switch (optional - used to set the offset frequency)
	power switch
	metal case
	4 sets mounting hardware, 4-40 sized

Step 2) Identify and orient the components: Most of the components should be fairly easy to identify and place - see the parts list and the parts placement diagram for descriptions. The LEDs must be oriented correctly to function - the anode (positive) side has a chamfer on one corner. Keep the LEDs on the paper until ready to solder, it's impossible to tell them apart visually. The LED anodes are all connected together and should be oriented towards the edge of the circuit board as shown on the parts placement diagram. The D11 and D12 diodes have a band or stripe to signify the cathode - it should be oriented as shown on the parts placement diagram and silk screen legend.

step 3) Place and solder the components on the circuit board: Use the parts placement diagram for information on the placement and orientation of the parts. Here is a suggested mount and solder sequence:

a) start with the power supply components: D12, C5, U3, C2 and R11
- these parts are located in the upper left part of the board
- D12 is the larger black diode, the cathode stripe should be to the right
- C5 is the .1 uF cap located just below D12
- U3 is the 78L05 voltage regulator located below C5
- C2 is another .1 uF cap located below U3
- R11 is a 10k ohm resistor marked 103 located to the right of C2

b) connect +V and ground to the holes left of D12 and C5
- use a meter to measure the output of U3, one place is the small hole to the right of R11,
- the meter ground connection can be made to one of the 4 corner mounting holes
- the meter should read roughly +5 Volts, if it doesn't recheck the soldering and connections

c) next continue with the 10 LEDs and associated resistors: D1-D10 and R1-R10
- R6, 4.7k ohm marked 472 located in the bottom middle of the board
- D6 the green LED also located at the bottom middle of the board with the chamfer towards the bottom edge of the board
- R1 to R5 and R7 to R10, 1k ohm all marked 102 located on either side of R6

D1 a red LED located at the bottom left of the board with the chamfer towards the bottom edge of the board
D2 a blue LED located to the right of D1, chamfer towards the bottom edge of the board
D3 a red LED located to the right of D2, chamfer towards the bottom edge of the board
D4 a red LED located to the right of D3, chamfer towards the bottom edge of the board
D5 an amber LED located to the right of D4, chamfer towards the bottom edge of the board
D7 2nd and last amber LED located to the right of D6, chamfer towards the bottom edge of the board
D8 a red LED located to the right of D7, chamfer towards the bottom edge of the board
D9 the last red LED located to the right of D8, chamfer towards the bottom edge of the board
D10 2nd and last blue LED located to the right of D9, chamfer towards the bottom edge of the board

d) apply power to the board, then use a clip lead or wire jumper with one end connected to ground
touch the wire momentarily to the top resistor pads (by the silk screen markings) for each of the 10 resistors
each LED should light up as it's resistor pad is touched by the wire
if an LED doesn't light, re-check the orientation and soldering

e) U1, the 18 pin wide body SO PIC16f627A, placed in the middle of the board oriented with the dimple at the upper left
center the chip on the pads, hold it down with a tweezers or some other means, tack solder one corner pin
recheck the orientation and alignment of the pins on the pads and if OK, tack solder the other corner – then proceed to finish soldering the remaining pins, clean up any solder shorts with desoldering braid

f) apply power to the board, the 9 LEDs should light sequentially from the blues inwards to the green and back out
if the LEDs don't light at all or one or more are missing, recheck the soldering, alignment and orientation

g) solder the remaining components:
C4, a .1 uf bypass cap located right above U1's dimple
C6, the only .22 uF cap located above C4
R17, a 100k ohm resistor marked 1003 to the right of C6
R16, the last 1k ohm resistor marked 102 below R17
D11, the only small black diode to the right of R17 with the stripe oriented to the right
C1, the last .1 uF bypass cap located to the right of R16
U2, the 8 pin SO op-amp marked 062C located to the right of C1 oriented as shown on the board picture (ST logo at pin 1)
as with the PIC, align the pins to the pads, solder a corner pin and recheck, then solder the rest and inspect and clean up and shorts or bad joints
R15, a 10k ohm resistor marked 103 to the right of U2
R14, another 10k ohm resistor marked 103 below R15
R13, the last 10k ohm resistor marked 103 below R14
R12, 2nd and last 100k ohm resistor marked 1003 to the left of R13
C7, the only 2.2 uF cap below R13
finally R100 (silk screen may show R10 by mistake) 100k ohm trimmer pot marked 104,
note that this part can be mounted on either side of the board per the builders preference

h) power up the board. The LEDs should light in sequence as in step f - if you don't see this pattern, power down the board immediately and recheck for solder shorts and reversed components. Otherwise connect the input jack and the optional momentary switch.

Setup and operation:

SMT Zerobeat requires two adjustments to work correctly. The first is the level setting of the pot. To adjust the level setting, use this sequence:

A) Turn on your radio and adjust the volume for normal listening levels. Set the radio for the CW mode and use the narrowest filtering available.

B) On a quiet band, tune in a station or carrier strong enough to actuate the signal strength meter of the radio - if you have a radio without an S meter, just use a station of moderate strength.

C) Connect SMT Zerobeat to the radio audio.

D) Adjust R10 pot using a small screwdriver until the detector LED (D1 – the leftmost LED) goes on in time with the Morse code sequence.

E) try changing the radio frequency and check that all the LEDs light up as the tuning knob is turned. Sometimes the level setting may need to be changed for higher/lower frequencies.

F) This adjustment may need to be touched up, but generally it is a set/forget adjustment. SMT Zerobeat will ***not*** work well on a noisy band or with very weak signals.

The second adjustment may not be necessary if SMT Zerobeat was pre-programmed for your transceiver's offset frequency.

If the SMT Zerobeat was NOT pre-programmed to your transceiver's offset the correct offset can be programmed easily by feeding a tone into the unit with a frequency equal to the desired offset. This tone must be loud enough to fully light the detect LED and it should be as "clean" (free of noise) as possible (Elecraft K2 owners should turn down the volume to zero when using the spotting tone). Then the optional momentary switch is pressed and held (PAH) until the SMT Zerobeat responds by lighting the three center LEDs (amber, green, amber). If the tone doesn't have enough volume OR if there is too much noise present, SMT Zerobeat may not correctly change the offset.

Note that the frequency display LED/s will stay lit with the last tone received even after the tone is turned off.

Also note that for a typical transceiver with 10 Hz resolution, there may be two or three frequencies at which the green LED will light - this is due to the 20 Hz “window” and also to the 5 Hz wide bins used by the PIC microcontroller in setting the center frequency.

If your radio has a "tracking" sidetone (sidetone frequency equal to the offset frequency), generating the offset frequency for the above procedure may be as easy as keying the transmitter and then pressing the switch on SMT Zerobeat. Some transceivers such as the Elecraft K2, have a spotting tone which can also be used to generate the offset frequency.

If your transceiver doesn't have either a tracking sidetone or spotting tone, the following sequence can be used to output a audio tone equal to the offset of your transceiver. The procedure is somewhat complicated and requires a separate ham band receiver, a dummy load, a stable signal source (it may be possible to use an off-the-air signal source), a crystal calibrator or crystal oscillator will work well. The procedure follows:

A) connect SMT Zerobeat to the separate ham band receiver/transceiver audio

B) connect the dummy load to the transceiver under "test"

C) turn on the signal source and the radios and tune them all to about the same frequency

D) tune the separate ham band receiver/transceiver to the signal source until the green LED on SMT Zerobeat lights up (it shouldn't matter what SMT Zerobeat is set to at this point).

E) turn off (or disconnect) the signal source

F) using the least power possible, key the transceiver under test (since it is connected to a dummy load, the following should be OK), then tune the transceiver's frequency until the green LED on SMT Zerobeat lights up. Stop the transmission from the transceiver (key up).

G) disconnect SMT Zerobeat from the separate receiver and connect it to the transceiver under test.

H) turn on (or connect) the signal source again.

I) The transceiver under test should be receiving a tone from the signal source. Without touching the transceiver frequency, press the switch on SMT Zerobeat to lock in the transceiver offset frequency.

The above procedure uses the SMT Zerobeat to first bring the transceiver transmit frequency and the signal source frequency within +/- 10 Hz of each other. Then since the signal source is exactly at the same transmit frequency as the transceiver, the received audio tone by the transceiver is the received offset frequency. There may be simpler ways of accomplishing this with less equipment, but the above should work in all cases.

One final alternative, if your transceiver documentation states the frequency offset, an audio signal generator can be set to that stated offset (using a frequency counter, 1 second gate time). This signal can then be fed into the SMT Zerobeat and then the switch is pressed to lock in the offset frequency into the memory of the PIC.

Circuit description: The SMT Zerobeat circuit has the following major circuit blocks:

1) power supply: a 78L05 regulator is used along with bypass capacitors to convert a +9 to +13.8 volt (12 volts nominal) input voltage to 5 volts.

2) audio processing: a dual op amp is used for audio processing. First the input audio is amplified 10 times. This first stage also adjusts the DC offset to 2.5 volts. Second the other half of the op amp is a half wave detector which converts the incoming audio to a DC level - the DC is filtered by C6 / R19.

3) processing and display: a PIC microcontroller is used to perform the major digital functions of the zerobeat display. Both the filtered audio and the detected audio are fed into the negative inputs of two comparators built into the PIC. These analog sections compare the input voltage to a common positive level set by the R10 pot. For example, if the detected audio is greater than the pot setting, the detector comparator output (pin 3 of the PIC) will go low. If the filtered audio is lower than the pot setting, the audio comparator output (pin 2 of the PIC) will go high. The detected audio comparator output is used to drive the detected LED. The PIC then accesses the comparator outputs. The detector comparator output is used to "gate" the PIC - no processing of tone data is done if a code element is not detected. The filtered audio comparator output is fed to the input of a hardware timer within the PIC. The timer uses this signal to gate a count of the PIC clock. This results in a measurement of the period of the audio input tone. The PIC then digitally filters this period measurement, then "bins" the result into 1 of 17 ranges. Each range corresponds to an LED output per the table at the beginning of this doc - the binning results in one of the 17 LED combinations being lit.

Modification ideas:

1) Included with the kit are ten .01 uF 1206 sized caps. They can be soldered on the bottom side of the board on the pads provided. The caps may minimize LED caused EMI coming from the SMT Zerobeat especially if the kit is mounted in a plastic enclosure and if the kit is used in close proximity to the antenna.

2) As mentioned before the 100k ohm trim pot can be mounted on either side of the board. Another idea is to use a regular panel mounted 100k ohm linear pot in place of the trim pot – this will make it easier to set the detection level.

3) If the LEDs are either too bright or too dim the user can change the series resistors (increase resistance to dim, decrease to brighten). The green LED is brighter than the others and will probably need a different value of resistor.

4) A quick & easy way to dim / diffuse the LEDs is to put a sticky back piece of Post-it note directly on the top of the LEDs. A more permanent option is to use regular white paper backed with double stick tape.

Please feel free to email with any questions, comments, suggestion or problems with this kit. My email address is:

wb9kzy at wb9kzy dot com

Thanks for choosing the SMT Zerobeat kit and Best Regards,

Building and Operating: SMT Zerobeat from Jackson Harbor Press

Chuck Olson, WB9KZY

List of parts included with the SMT Zerobeat kit:

Ref	marking	Description
C1		.1 uf 1206 sized cap
C2		.1 uf 1206 sized cap
C3		C3 is not used in this kit
C4		.1 uf 1206 sized cap
C5		.1 uf 1206 sized cap
C6		.22 uf 1206 sized cap
C7		2.2 uf 1206 sized cap
D1		red smt LED
D2		blue smt LED
D3		red smt LED
D4		red smt LED
D5		amber smt LED
D6		green smt LED
D7		amber smt LED
D8		red smt LED
D9		red smt LED
D10		blue smt LED
D11	stripe SJ	small smt diode, stripe = cathode
D12	stripe M7	larger 1 A power diode, stripe = cathode
R1	102	1k ohm 1206 sized resistor
R2	102	1k ohm 1206 sized resistor
R3	102	1k ohm 1206 sized resistor
R4	102	1k ohm 1206 sized resistor
R5	102	1k ohm 1206 sized resistor
R6	472	4.7k ohm 1206 sized resistor
R7	102	1k ohm 1206 sized resistor
R8	102	1k ohm 1206 sized resistor
R9	102	1k ohm 1206 sized resistor
R10	102	1k ohm 1206 sized resistor
R11	103	10k ohm 1206 sized resistor
R12	1003	100k ohm 1206 sized resistor
R13	103	10k ohm 1206 sized resistor
R14	103	10k ohm 1206 sized resistor
R15	103	10k ohm 1206 sized resistor
R16	102	1k ohm 1206 sized resistor
R17	1003	100k ohm 1206 sized resistor
R100	104	100K trimmer pot (orange or blue top, + screwdriver slots)
U1	PIC16F627A	programmed PIC microcontroller, 18 pin SO
U2	062C	TL062 op amp, 8 pin SO
U3	F5 8B	78L05A, 5V, 100 ma regulator SOT-89
		SMT Zerobeat circuit board

off-board items (not included with the kit):

SW1	momentary switch
	power switch
J1	+12V power jack
J2	audio input jack
	4 sets mounting hardware, 4-40 or M3 sized