Building and Operating:
Son of Zerobeat
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: Son of Zerobeat, is my 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. Son of Zerobeat has an array of 7 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:

| | |
|---|---|
| leftmost red: | -110 Hz and below |
| red-red | -90 to -110 Hz |
| second red | -70 to -90 Hz |
| red-yellow | -50 to -70 Hz |
| yellow | -30 to -50 Hz |
| yellow-green | -10 to -30 Hz |
| green | +/- 10 Hz |
| green-yellow | +10 to +30 Hz |
| yellow | +30 to +50 Hz |
| yellow-red | +50 to +70 Hz |
| red | +70 to +90 Hz |
| red-red | +90 to +110 Hz |
| rightmost red | +110 Hz and above |

There is an additional LED 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, Son of Zerobeat is preset to a center frequency of 600 Hz.

## General notes on building Son of Zerobeat

One decision the builder should make before starting construction of Son of Zerobeat is how the project will be mounted in the case. This is important since it will determine how the LEDs are mounted on the board. Basically the builder has the choice of mounting the LEDs either perpendicular to the circuit board (straight leads) or parallel to the circuit board (right angle leads). The builder may also elect to use their own LEDs instead of the ones supplied with the kit - round LEDs have a clear mounting advantage over the rectangular LED supplied. The builder may also wish to use higher brightness LEDs - in that case, the appropriately higher valued resistors would be mounted on the circuit board. 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.

A rectangular hole in the 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. The leads on the LEDs can be used to support the front part of the circuit board either totally or partially (use only one or none of the front 4-40 sized mounting holes). Then just the back mounting holes can be used to hold the board in place. One builder clamped all the LEDs together and then spread a layer of super glue on top to temporarily hold them together. The leads can also be formed while the LEDs are clamped together. Be careful with the glue as it will not only stick your fingers together, it can also cloud the LEDs. Rubber bands can also be used to hold the LEDs together before inserting them through the rectangular mounting hole. Note that the longer the LED leads are left, the easier it will be to adjust the board into place.

The components should be inserted a few at a time, soldered in place and then clip the leads. The pads and traces are small and delicate - a small tipped, low power (25 watts or less) soldering iron should be used.

Machined pin SIP sockets (not supplied) can be used to provide the connection points to the off-board components. Then the builder will be able to plug the wires from the components into the SIP sockets which simplifies moving the unit in and out of the enclosure. The builder might also consider using these sockets for the voltage regulator. The machined pin sockets are available from most of the mail order surplus electronics parts suppliers. Another way to make the off-board connections is to solder a post to the connection points. Then the wires to the off-board items can be soldered to the post rather than directly to circuit board.

Finally, the integrated circuits, U2 and U3, 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 inserting the ICs.

Building the Son of 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 | 12V power connector |
| J2 | audio input connector |
| SW1 | momentary SPST switch (optional - used to set the offset frequency) |
| | 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. There are four .1 uf multilayer ceramic bypass capacitors and two .1 uf polyester capacitors - they can be distinguished from each other by their size, the four bypass caps are small, blue or yellow parts with .1 inch lead spacing while the two polyester caps are larger dark red parts with .2 inch lead spacing. The 3 electrolytic caps are clearly marked as to value and polarity - be sure to orient the negative stripe correctly per the parts placement diagram. The LEDs must be oriented correctly to function - the anode (positive) leads are slightly longer than the cathode (negative) leads. The LED anodes are all connected together and should be oriented towards the bottom edge of the circuit board as shown on the parts placement diagram. D9, the 1n4148 switching diode, has a black band to signify the cathode - it should be oriented as shown on the parts placement diagram.

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. Clip the leads after soldering. The horizontal resistors should have their leads formed with a .4 inch spacing. The vertically mounted resistors and diode should have their leads formed by just bending over one lead until it is pointing the direction of the other lead. I would recommend that the builder insert parts by their profile (or height) above the circuit board starting with the lowest and working up. Here is a suggested mount, solder and clip sequence:

a) DIP sockets - both should be inserted with the notch towards the top edge of the board

b) C1 and C14, the .1 uf bypass caps next to the DIP sockets

c) crystal, X1 and the two 22 pf ceramic disc capacitors to the right of the U2 socket

d) horizontally mounted resistors, including:
eight 150 ohm LED resistors (R1 and R3 to R9) to the left and right of the U2 socket
the 2.4k (R16) resistor just above the U3 socket (IC on the left side of the board)
the 1k (R20) resistor just above the U2 socket (IC on the right side of the board)
and finally the two 10K resistors (R13 and R14) near the top center of the board.

e) U1 (78L05 5V regulator) with flat side away from the top edge of the board.

f) two .1 uf bypass caps (C4 and C5) on either side of U1


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g) 100k trimmer pot to the left of the 18 pin socket

h) .01 uf polyester cap (C8) at the top center of the board

i) .022 uf polyester cap (C9) at the left of U3 (next to the bypass cap)

j) vertical 2.4k resistor (R17) at the left of U3

k) vertical 10k resistor (R11) above U3

l) vertical 2.4k resistors (R18, R19) below U3

m) .022 uf polyester cap (C10) at the bottom of U3 (below the two 2.4k resistors just mounted)

n) .1 uf polyester cap (C12) at the bottom of U3 (left of the two 2.4k resistors just mounted)

o) .1 uf polyester cap (C11) at the top left of U3

p) vertical 100k resistor (R15) right of U3 pins 13 and 14

q) vertical 10k resistor (R12) right of 100k resistor just mounted

r) vertical 10k resistor (R2) below 10k resistor just mounted

s) vertical diode (D9) right of U3 pins 8 and 9 with cathode (band) towards pin 9

t) vertical 100k resistor (R21) right of diode just mounted

u) vertical 1 uf electrolytic cap (C13) below diode just mounted, negative stripe towards bottom edge of board

v) vertical 2.2 uf non-polarized electrolytic cap (C7) at top left of board next to IN marking

w) vertical 22 uf electrolytic cap (C3) at top right of board with negative stripe to the top edge of board

x) 8 LEDs near the bottom right edge of the board - the longer lead (anode) should be mounted towards the bottom of the board (common connection). The colors should be mounted: Red Red Red Yellow Green Yellow Red Red
As mentioned above in the General note, the user should form the leads of the LEDs to fit the planned enclosure.

Step 4) Check the board: Before proceeding, take the time to check the bottom of the board for solder bridges. Use the bottom view diagram as a guide to visually check for these shorts. It may help to clean the flux from the board and then use a strong light in conjunction with a magnifying glass to see these problems. Also, double check the orientation of the critical components such as the diodes and regulator (U1). After you are convinced that the board is OK and after you have formed the leads of ICs U2 and U3 to fit in the sockets, insert the ICs into their respective sockets, being sure to follow the parts placement diagram for proper orientation (pin 1 indicated by a notch or dimple should be to the top edge of the board. Finally, connect the power connector, optional switch and audio input connector as shown on the parts placement diagram.

Next, power up the board. The LEDs should light in sequence (in pairs) from the two outer Red LEDs to the center Green LED and back again and finally all LEDs should go off. If you don't see this pattern, power down the board immediately and recheck for solder shorts and reversed components.

Setup and operation: Son of Zerobeat requires two adjustments to work correctly. The first is the level setting of the R10 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 Son of Zerobeat to the radio audio.

D) Adjust R10 pot using a small screwdriver until the detector LED (D8 - the one separate from the 7 other LEDs) goes on in time with the Morse code sequence.

E) try changing the radio frequency and check that all the 7 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. Son of Zerobeat will not work well on a noisy band or with very weak signals.

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

If the Son of 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, Son of Zerobeat will respond by lighting the three center LEDs (yellow, green, yellow). If the tone doesn't have enough volume OR if there is too much noise present, Son of 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 Son of 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 Son of 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 Son of Zerobeat lights up (it shouldn't matter what Son of Zerobeat is set to at this point).


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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 Son of Zerobeat lights up.  Stop the transmission from the transceiver (key up).

G) disconnect Son of 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 Son of Zerobeat to lock in the transceiver offset frequency.

The above procedure uses the Son of 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 Son of Zerobeat and then the switch is pressed to lock in the offset frequency into the memory of the PIC.

Circuit description:   The Son of 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 quad section rail-to-rail op amp is used  for all audio processing.  First the input audio is amplified 10 times.  This first stage also adjusts the DC offset to 2.5 volts.  The next two stages are 1400 Hz low pass filter sections each with a gain of 1.  This filtering should eliminate some of the high frequency noise that can affect the zerobeat display.  The final section of the op amp is a half wave detector which converts the incoming audio to a DC level - the DC is filtered by C13 / R21.

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 13 ranges.  Each range corresponds to an LED output per the table at the beginning of this doc - the binning results in one of the 13 LED combinations being lit.

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

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Thanks for choosing the Son of Zerobeat kit and
Best Regards,

Chuck Olson, WB9KZY

List of parts included with the Son of Zerobeat kit:

| Ref | marking | Description |
|---|---|---|
| ----- | ----------- | ----------------- |
| C1 | .1M or 104 | .1 uf multilayer ceramic .1" lead space cap |
| C2 | 22 | 22 pf NPO ceramic disc capacitor, .1" lead space |
| C3 | 22 uF 25 V | 22 uf radial (upright) electrolytic capacitor |
| C4 | .1M or 104 | .1 uf multilayer ceramic .1" lead space cap |
| C5 | .1M or 104 | .1 uf multilayer ceramic .1" lead space cap |
| C6 | 22 | 22 pf NPO ceramic disc capacitor, .1" lead space |
| C7 | 2.2 uF 50V | 2.2 uf radial (upright) non-polarized electrolytic capacitor |
| C8 | 103J | .01 uf polyester (dark red), .2" lead space cap |
| C9 | 223J | .022 uf polyester (dark red), .2" LS cap |
| C10 | 223J | .022 uf polyester (dark red), .2" LS cap |
| C11 | 104J | .1 uf polyester (dark red), .2" lead space cap |
| C12 | 104J | .1 uf polyester (dark red), .2" lead space cap |
| C13 | 1 uF 50V | 1 uf radial (upright) electrolytic capacitor |
| C14 | .1M or 104 | .1 uf multilayer ceramic .1" lead space cap |
| D1 | | Red rectangular LED (anode is long lead) |
| D2 | | Red rectangular LED (anode is long lead) |
| D3 | | Yellow rectangular LED (anode is long lead) |
| D4 | | Green rectangular LED (anode = long lead) |
| D5 | | Yellow rectangular LED (anode is long lead) |
| D6 | | Red rectangular LED (anode is long lead) |
| D7 | | Red rectangular LED (anode is long lead) |
| D8 | | Red rectangular LED (anode is long lead) |
| D9 | | 1n4148 diode, glass package, cathode = stripe |
| R1 | brown green brown gold | 150 ohm 1/4 watt resistor |
| R2 | brown black orange gold | 10K ohm 1/4 watt resistor |
| R3 | brown green brown gold | 150 ohm 1/4 watt resistor |
| R4 | brown green brown gold | 150 ohm 1/4 watt resistor |
| R5 | brown green brown gold | 150 ohm 1/4 watt resistor |
| R6 | brown green brown gold | 150 ohm 1/4 watt resistor |
| R7 | brown green brown gold | 150 ohm 1/4 watt resistor |
| R8 | brown green brown gold | 150 ohm 1/4 watt resistor |
| R9 | brown green brown gold | 150 ohm 1/4 watt resistor |
| R10 | 104 | 100K trimmer pot (orange top, + screwdriver slots) |
| R11 | brown black orange gold | 10K ohm 1/4 watt resistor |
| R12 | brown black orange gold | 10K ohm 1/4 watt resistor |
| R13 | brown black orange gold | 10K ohm 1/4 watt resistor |
| R14 | brown black orange gold | 10K ohm 1/4 watt resistor |
| R15 | brown black yellow gold | 100K ohm 1/4 watt resistor |
| R16 | red yellow red gold | 2.4K ohm 1/4 watt resistor |
| R17 | red yellow red gold | 2.4K ohm 1/4 watt resistor |
| R18 | red yellow red gold | 2.4K ohm 1/4 watt resistor |
| R19 | red yellow red gold | 2.4K ohm 1/4 watt resistor |
| R20 | brown black red gold | 1K ohm 1/4 watt resistor |
| R21 | brown black yellow gold | 100K ohm 1/4 watt resistor |
| U1 | LM78L05ACZ | 5V, 100 ma regulator in TO-92 case |
| U2 | PIC16F628-04/P | programmed PIC microcontroller, 18 pin DIP |
| U3 | TLC2274CN | rail to rail op amp, 14 pin DIP |
| X1 | 4.000 | 4 MHz crystal, HC49-S case |
| | | 14 pin machined pin socket (for op-amp, U3) |
| | | 18 pin machined pin socket (for PIC, U2) |



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