Building and Operating:
The Grandson of 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: Grandson of Zerobeat, is my 2nd 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. Grandson of Zerobeat has an array of 10 LEDs (note: two green ones light up as one) 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 (note: the indication can be reversed with a switch press and release):

| | |
|---|---|
| leftmost red: | -150 to -170 Hz and above |
| red-red | -130 to -150 Hz |
| red: | -110 to -130 Hz |
| red-yellow | -90 to -110 Hz |
| 2nd yellow | -70 to -90 Hz |
| yellow-yellow | -50 to -70 Hz |
| yellow | -30 to -50 Hz |
| yellow-greens | -10 to -30 Hz |
| greens | +/- 10 Hz |
| greens-yellow | +10 to +30 Hz |
| yellow | +30 to +50 Hz |
| yellow-yellow | +50 to +70 Hz |
| 2nd yellow | +70 to +90 Hz |
| yellow-red | +90 to +110 Hz |
| red | +110 to +130 Hz |
| red-red | +130 to +150 Hz |
| rightmost red: | +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, Grandson of Zerobeat is preset to a center frequency of 600 Hz.

Why the Grandson ? The Son of Zerobeat kit has sold fairly well for 13 years but a couple of things happened to inspire this slightly updated version. First, my original beta tester, Dick, K9LW, made a couple of suggestions:

One was to add a couple more LEDs to indicate the frequency – this was fairly easy to do after the crystal used in the original was eliminated thus freeing two pins for the extra LEDs – although this might affect the accuracy of the kit slightly, it's felt that 9 LEDs blinkin are more fun than just 7.

A second suggestion was to add an easy way to change the LED “direction” - this was prompted by the fact that many multiband rigs will flip the sideband used for CW from LSB on the lower bands to USB on the higher bands (with an Elecraft K2 this happens with 15 meters). When USB is used the audio frequency of a CW signal will decrease as the dial frequency is increased. The Grandson of Zerobeat allows the user to flip the LED display with a Press And Release (PAR) of the switch, the leftmost LED will then indicate +150 to +170 Hz. The display can be toggled back to normal with another PAR of the switch. Note that this change in “direction” will NOT be retained in memory after a power down of the kit.

A third change was to eliminate the low pass audio filter circuitry – this reduces the cost of the kit slightly without really affecting the performance.

One final change to the Grandson of Zerobeat kit was to substitute an HP 10 LED array for the previously used discrete LEDs. This will hopefully make assembly a little easier. Note that the detector LED is still separate from the LED array.

## General notes on building the Grandson of Zerobeat:

One decision the builder should make before starting construction of Grandson of 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 in a separate 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 !

The builder has the choice of mounting the LEDs on either side of the circuit board. 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 array 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. Another substitution I've made is a 7 segment LED display turned sideways in place of the LED array. Two extra round LEDs were added – the decimal point LED in the 7 segment display was used for the detector. 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 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.

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 Grandson 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. The 2 electrolytic caps are clearly marked as to value and polarity - be sure to orient the negative stripe on C3 correctly per the parts placement diagram. The detector LED must be oriented correctly to function - the anode (positive) lead is slightly longer than the cathode (negative) lead. The LED array has printing on the anode side of the package. 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 D12 and D13 diodes have a 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 diodes should have their leads formed by just bending over one lead until it is pointing the direction of the other lead – see the picture on the parts placement guide. 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 – the 18 pin socket should be mounted with the notch towards the left side of the board – the 20 and 8 pin sockets should be mounted with the notch towards the bottom side of the board.

b) C1 and C2, the .1 uf bypass caps next to the DIP sockets

c) the resistors, including:

ten 180 (brown-gray-brown-gold) ohm LED resistors (R1, R3 to R8, R12, R16, R17) to the left and right of the U2 socket
the 150 (brown-green-brown-gold) ohm LED resistor (R9) below R17
the 10k (brown-black-orange-gold) ohm, 5% resistor (R2) below U2
the 1k (brown-black-red-gold) ohm resistor (R18) just to the left of C2 (on the left side of the board)
a 100k (brown-black-yellow-gold) ohm resistor (R19) just to the left of R18 (on the left side of the board)
a blue 10K ohm resistor 1% (R14) to the left of U3
a blue 10K ohm resistor 1% (R13) to the top of U3
a 100k (brown-black-yellow-gold) ohm resistor (R15) just to the right of U3
a blue 10K ohm resistor 1% (R11) to the right of R15

d) C4, a .1 uf bypass cap located right above the K in the WB9KZY board marking

e) U1 (78L05 5V regulator) to the left of C4 with flat side towards the top edge of the board.

f) C5, a .1 uf bypass cap between C3 and the mounting hole, lower left corner of the board – note that C5 can't be seen in the parts placement pictorial but it is there, obscured by C3. C5 can be seen in the picture on the Grandson of Zerobeat web page

g) 100k ohm trimmer pot center left bottom edge of the board

h) .22 uf polyester cap (C6) directly above R19

i) vertical glass diode (D13) between C6 and R14 with cathode (band) towards the top edge of the board

j) vertical 2.2 uf non-polarized electrolytic cap (C7) at top center of board next to IN marking – I would leave the leads of C7 long to allow bending it over to lower the profile of the board

k) vertical 10 uf electrolytic cap (C3) at bottom left corner of board with negative stripe to the left edge of board – I would leave the leads of C3 long to allow bending it over to lower the profile of the board

l) vertical epoxy diode (D12) between C3 and the R10 pot at bottom left corner of the board with the cathode towards the top edge of the board

m) D11, the red LED (I would solder this in after putting the LED array in the socket so that it can be made flush with the top of the LED array) to the bottom of the 20 pin socket with the cathode (short lead) towards the center of the board and the anode (longer lead) towards the edge of the board

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. The LED array pins may need some forming before insertion into the 20 pin socket – the builder should consider a breakfast of

Wheaties before attempting to put the LED array into the socket, it won't be easy ! The printed edge of the LED array (anode side) should be towards the edge of the board. Connect the power connector, optional switch and audio input connector as shown on the parts placement diagram. Finally, adjust the pot (R10) to roughly the 1 o'clock position (just clockwise from mid rotation).

Next, power up the board. The LEDs should light in sequence (in pairs) from the two outer Red LEDs to the two center Green LEDs 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: Grandson 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 Grandson of Zerobeat to the radio audio.

D) Adjust R10 pot using a small screwdriver until the detector LED (D11 - the one separate from the LED array) 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. Grandson of Zerobeat will not work well on a noisy band or with very weak signals.

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

If the Grandson 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 and held (PAH) until the Grandson of Zerobeat responds 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, Grandson 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 LEDs 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 Grandson 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 Grandson 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 LEDs on Grandson of Zerobeat light up (it shouldn't matter what Grandson of 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 LEDs on Grandson of Zerobeat light up.  Stop the transmission from the transceiver (key up).

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

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

Circuit description:  The Grandson 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 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.

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 Grandson of Zerobeat kit and Best Regards,

Chuck Olson, WB9KZY



## List of parts included with the Grandson of Zerobeat kit:

| Ref | marking | Description |
|---|---|---|
| C1 | .1M or 104 | .1 uf multilayer ceramic .1" lead space cap |
| C2 | .1M or 104 | .1 uf multilayer ceramic .1" lead space cap |
| C3 | 10 uF 25 V | 10 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 or 224 | .22 uf polyester (dark red or white box), .2" lead space cap |
| C7 | 2.2 uF 50V | 2.2 uf radial (upright) non-polarized electrolytic capacitor |
| D1-10 | HDSP-4836 | 20 pin DIP, 10 LED array: 2 red, 2 yellow, 2 green, 2 yellow, 2 red, anode side has printing on it |
| D11 | | Red rectangular LED (anode is long lead) |
| D12 | 1n400x (x=0 to 7) | 1 A power diode, black package, cathode = stripe |
| D13 | 1n4148 | 1n4148 diode, glass package, cathode = stripe |
| R1 | brown gray brown gold | 180 ohm 1/4 watt resistor, 5% |
| R2 | brown black orange gold | 10K ohm 1/4 watt resistor, 5% |
| R3 | brown gray brown gold | 180 ohm 1/4 watt resistor, 5% |
| R4 | brown gray brown gold | 180 ohm 1/4 watt resistor, 5% |
| R5 | brown gray brown gold | 180 ohm 1/4 watt resistor, 5% |
| R6 | brown gray brown gold | 180 ohm 1/4 watt resistor, 5% |
| R7 | brown gray brown gold | 180 ohm 1/4 watt resistor, 5% |
| R8 | brown gray brown gold | 180 ohm 1/4 watt resistor, 5% |
| R9 | brown green brown gold | 150 ohm 1/4 watt resistor |
| R10 | 104 | 100K trimmer pot (orange top, + screwdriver slots) |
| R11 | brown black black red brown | 10K ohm 1/4 watt resistor, 1% blue metal film |
| R12 | brown gray brown gold | 180 ohm 1/4 watt resistor, 5% |
| R13 | brown black black red brown | 10K ohm 1/4 watt resistor, 1% blue metal film |
| R14 | brown black black red brown | 10K ohm 1/4 watt resistor, 1% blue metal film |
| R15 | brown black yellow gold | 100K ohm 1/4 watt resistor |
| R16 | brown gray brown gold | 180 ohm 1/4 watt resistor, 5% |
| R17 | brown gray brown gold | 180 ohm 1/4 watt resistor, 5% |
| R18 | brown black red gold | 1K ohm 1/4 watt resistor |
| R19 | brown black yellow gold | 100K ohm 1/4 watt resistor |
| U1 | 78L05A | 5V, 100 ma regulator in TO-92 case |
| U2 | PIC16F628A or 627A | programmed PIC microcontroller, 18 pin DIP |
| U3 | TL062 | op amp, 8 pin DIP |
| | | Grandson of Zerobeat circuit board |
| | | 8 pin machined pin socket (for op-amp, U3) |
| | | 18 pin machined pin socket (for PIC, U2) |
| | | 20 pin machined pin socket (for LED array) |

off-board, unprovided items:

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



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