Building and Operating:
The Grandson of Zerobeat RA kit (5mm LED version)
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 RA (Right Angle display), is my 4th 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 RA has 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 (note: the indication can be reversed with a switch press and release):

blue	-150 to -170 Hz and above
blue-red	-130 to -150 Hz
red	-110 to -130 Hz
red-red	-90 to -110 Hz
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
red	+110 to +130 Hz
red-blue	+130 to +150 Hz
blue	+150 to +170 Hz and above

There is an additional red 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 (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 RA is preset to a center frequency of 600 Hz.

Why the Grandson RA ? The Grandson of Zerobeat kit has sold well for 6 years (and will continue to be sold) but a customer had a problem with his Grandson of Zerobeat kit when he tried to remove the socket and mount the LED array on the end of a ribbon cable. This prompted the idea of moving the LEDs to a daughter board which could either be remoted using a ribbon cable or a right angle mounting using a standard tenth inch right angle header. In addition a simple voltage regulator circuit was added to dim the LEDs. Finally the daughter boards have pads for mounting optional .01 uF caps to minimize EMI from the LEDs.

General notes on building the Grandson of Zerobeat RA:

One decision the builder should make before starting construction of Grandson of Zerobeat RA 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 !

10 round 5 mm holes will be needed for the 5mm LED version - I usually mark the case (using an awl) for the 10 holes using either 0.1” perf board (the holes should be 0.3” apart) or the LED daughter board (holes for the LEDs are 0.3” apart).

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. Yet another way to make off-board connections easier is to use .1" headers and jumpers which are popular in the Arduino universe.

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 RA :

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)
	case
	4 sets mounting hardware, 4-40 sized (or M3)

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. Unfortunately the LEDs are all clear so either the tape holding them has been marked with their color or the bag holding them has been marked. The LEDs must be oriented correctly to function - the anode (positive) lead is slightly longer than the cathode (negative) lead. The LED cathode also has a slightly flat side. The D12 and D13 diodes have a band to signify the cathode - they should be oriented as shown on the parts placement diagram with the cathode side marked with a minus sign on the silk screen.

step 3) Place and solder the components on the main 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 0.4 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 8 pin socket should be mounted with the notch towards the bottom edge of the board.

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

c) the resistors, including:

- ten LED resistors (R1, R3 to R9, R12, R16, R17) on either side of the U2 socket
- the 10k (brown-black-orange-gold) ohm, 5% resistor (R2) next to 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 to the left of R2 (10k ohm 5%)

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

g) R10, a 100k ohm trimmer pot center left bottom edge of the board

h) .22 uf polyester cap (C6 a white box cap) 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 if desired

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 if desired

l) vertical epoxy diode (D12) between C5 and the R10 pot at bottom left corner of the board with the cathode towards the top edge of the board

step 4) Place and solder the components on the 5mm LED daughter board:

a) optional: the 10 x .01 uF bypass capacitors (yellow, marked 103) on the back of the board as shown, trim the leads

b) the LEDs with the long lead (anode) to the top edge of the board and the cathode (flatted side) to the bottom edge of the board

e) the 300 ohm resistor on the back of the board near the side edge of the board

f) the LM317 regulator IC on the back of the board with the flat face towards the mounting hole

g) the 1K ohm trim pot on the back of the board

h) the 13 pin right angle header on the back of the board as shown

Step 5) mate the display daughter board to the main board. Use the supplied right angle hardware to help with alignment – then solder.

Step 6) Check the boards: 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 regulators (U1 and LM317). After you are convinced that the boards are 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.

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) – also adjust the 1k LED brightness pot fully clockwise.

Next, power up the board. The LEDs should light in sequence (in pairs) from the two outer blue 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: Grandson of Zerobeat RA 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 RA 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 RA will not work well on a noisy band or with very weak signals.

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

If the Grandson of Zerobeat RA 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 RA 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 RA 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 RA. 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 RA 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 RA light up (it shouldn't matter what Grandson of Zerobeat RA 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 RA light up. Stop the transmission from the transceiver (key up).

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

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

Circuit description: The Grandson of Zerobeat RA 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. In addition, a LM317 regulator, a 1k ohm pot and a 300 ohm resistor are used on the display board to control the LED brightness.

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 RA kit and Best Regards,

Chuck Olson, WB9KZY

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

Ref	marking	Description
main board:		
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 (white box), .2" lead space cap
C7	2.2 uF 50V	2.2 uf radial (upright) non-polarized electrolytic capacitor
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 green brown gold	150 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 gray brown gold	180 ohm 1/4 watt resistor, 5%
R10	104	100K trimmer pot
R11	brown black black red brown	10K ohm 1/4 watt resistor, 1% blue metal film
R12	brown red brown gold	120 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	not used for the 5mm daughter board	
R17	brown red brown gold	120 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 RA main circuit board
		8 pin machined pin socket (for op-amp, U3)
		18 pin machined pin socket (for PIC, U2)
Daughter board:		
		Grandson of Zerobeat RA daughter board 5mm
D1	***clear***	***blue 5mm LED (flat side is cathode, anode is long lead)*** ***extra red LED also included for D1***
D2	***clear***	***red 5mm LED (flat side is cathode, anode is long lead)***
D3	***clear***	***red 5mm LED (flat side is cathode, anode is long lead)***
D4	***clear***	***yellow 5mm LED (flat side is cathode, anode is long lead)***
D5	***clear***	***green 5mm LED (flat side is cathode, anode is long lead)***
D6	***D6 is not used on the 5mm daughter board***	
D7	***clear***	***yellow 5mm LED (flat side is cathode, anode is long lead)***
D8	***clear***	***red 5mm LED (flat side is cathode, anode is long lead)***
D9	***clear***	***red 5mm LED (flat side is cathode, anode is long lead)***
D10	***clear***	***blue 5mm LED (flat side is cathode, anode is long lead)*** ***extra red LED also included for D10***
D11	***clear***	***red 5mm LED (flat side is cathode, anode is long lead)***
	LM317	***TO-92 regulator on back of daughter board***
	orange black brown gold	***300 ohm resistor on back of daughter board***
	102	***1k ohm right angle trim pot on back of daughter board***
	103	***10 x yellow .01 uF bypass capacitors on back of daughter board***
off-board, unprovided items:		
SW1		momentary switch
J1		+12V power jack
J2		audio input jack
		4 sets mounting hardware, 4-40 sized