# Examining and Modifying Marker Generator Output

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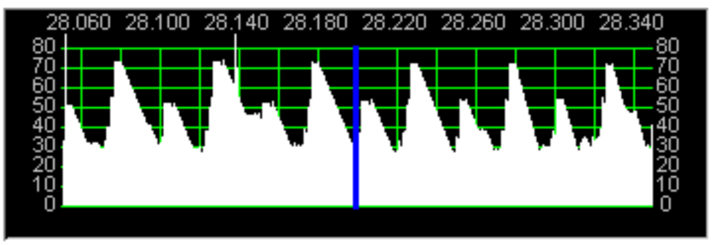
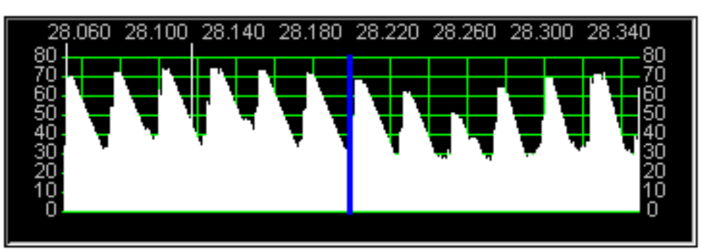
Recently, I received an email mentioning missing 5 KHz markers with a VE3DNL marker generator kit (note 1). The odd markers came through loud and clear while the even markers were not to be heard. I emailed back explaining that the square wave output of the marker generator was ideally composed of ONLY the odd harmonics of the fundamental - luckily the output wave form is not ideal and the even harmonics are present, just weaker than the odd harmonics. Here is an example of this with a 25 Khz marker - a square wave with a 50% duty cycle (20 microseconds (us) at 5V, 20 us at 0V). This is a screen shot from a Ten-Tec RX-320 (note 2) sweep of 300 Khz of 10 Meters, centered at 28.2 Mhz: The even harmonics are roughly 20 db below the level of the odd harmonics. The RX-320 is not a spectrum analyzer, but it does provide a useful graphical plot of what any receiver will hear. The marker generator was coupled to the antenna input of the RX-320 with a gimmick capacitor (two insulated lenths of #24 solid wire which have been twisted together tightly for 6 inches).

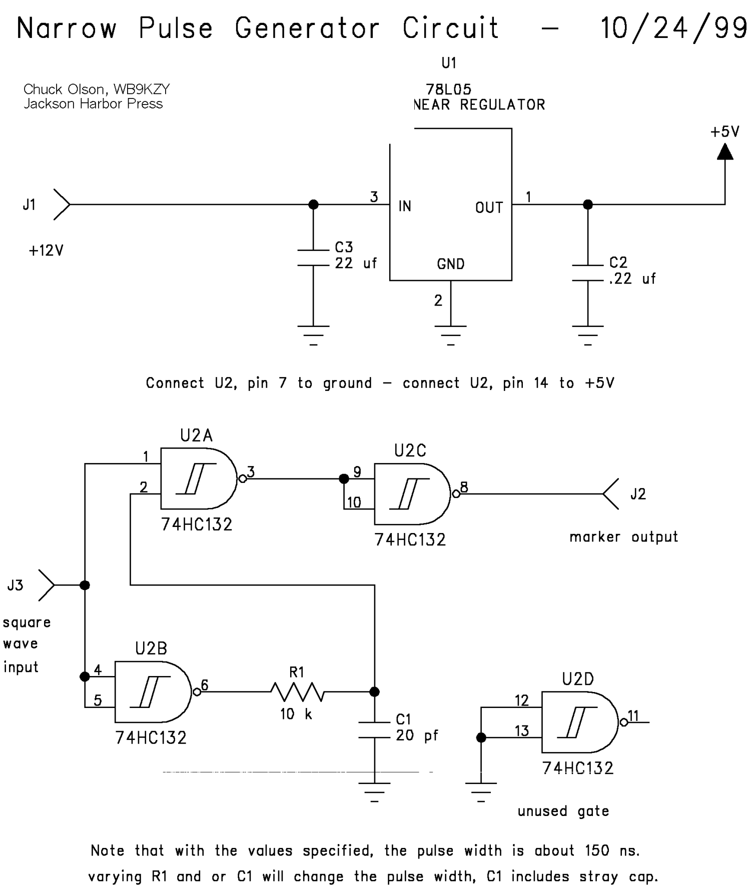



Spectrum of a 50% duty cyc. square wave on 10 meters - centered at 28.2 MHz.

After this email, there were some emails on QRP-L concerning the Tuna-Tin 2 - the discussion of the TT2 moved into the question of harmonic content of square waves and the effect of different duty cycles on the harmonic levels. A mention was made by Nick, WA5BDU, (note 3) that the even harmonics seemed stronger as the duty cycle was lower. I tried changing the duty cycle of the PIC marker generator to 10% (at 25 KHZ, this is 4 us at 5V and 36 us at 0v). The results were interesting - as seen here, the signal varies smoothly in a inverted bowl shaped pattern. Most of the

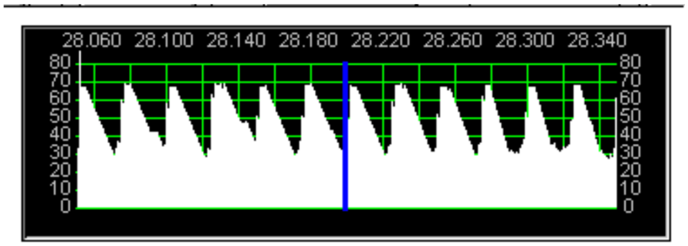



Spectrum of a 10% duty cycle square wave at a 25 KHz rate - center: 28.2 MHz even harmonic markers are stronger, but not all.

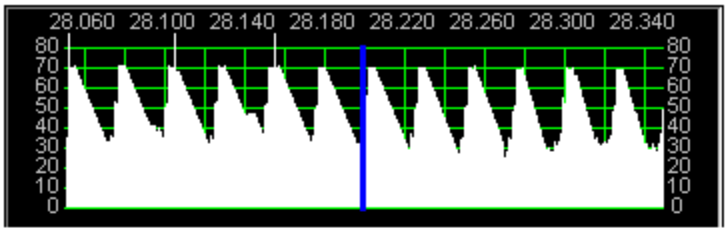



Next, another thread started on QRP-L concerning the variation in signal strength of square wave markers. John, KU4AF, mentioned that a modern marker generator uses a narrow pulse instead of a square wave to generate an output where the markers are all at roughly the same amplitude (notes 4, 5). I got out my copy of "The Art of Electronics" and found a nice little circuit on page 557 for making narrow pulses on the leading (0V to 5V) edge of a square wave. The circuit is shown here using a 74HC132 NAND gate - a 74HC00 NAND gate could also be used, but the HC132 is less likely to oscillate due to the hysteresis on the input pins. If R1 is jumpered, the resulting pulse will be less than 10 nanoseconds (ns) in width. With R1 at 10K, the pulse will be roughly 160 ns wide. The value of C1 is just a guess - C1 is composed of the stray capacitance inherent in the solderless breadboard used. If another 22 pf is added at C1, the pulse width will exceed 300 ns. See note 6 for more circuit information.

Here is a spectral display of the 160 ns wide pulse repeated at the 25 Khz rate. The amplitudes of the odd and even harmonics are very close - their overall strength is also quite good - I reported different results on QRP-L (the pulsed markers were about the same level as the even markers are with a 50% duty cycle square wave) - I'm not sure why the results would vary - it may be due to using the RX-320 instead of a "real" spectrum analyzer.

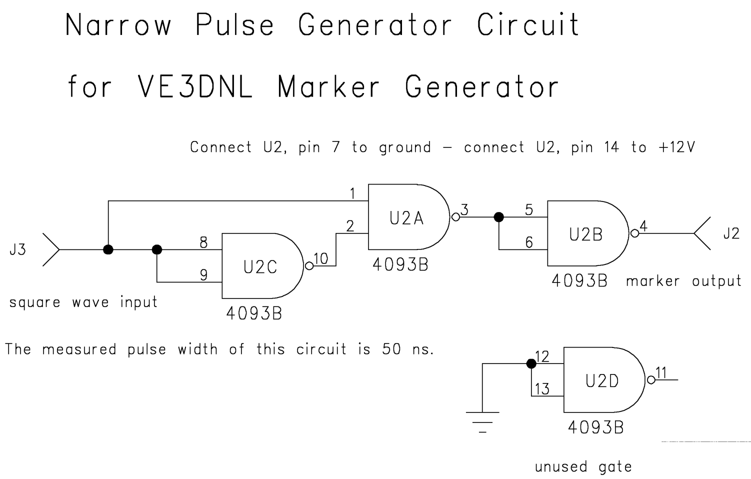



Spectrum of a 160 ns pulse at a 25 KHz rate on the 10 meter band, center 28.2 MHz

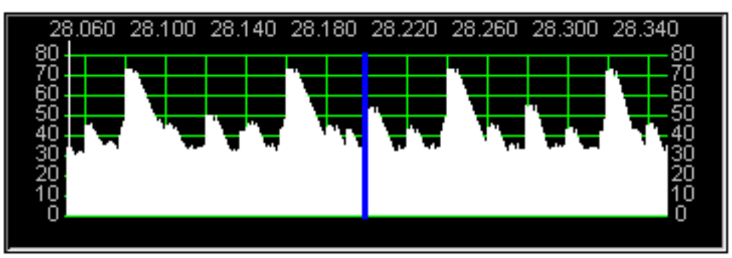



Spectrum of 10 ns wide pulses at a 25 KHz rate on the 10 meter band centered at 28.2 MHz.

Here is a picture of the spectrum with a 10 ns wide pulse. The markers are still quite uniform in amplitude - also the signal strength is even higher than with the 160 ns wide pulses. This seems counterintuitive, since I would presume that a fatter pulse has more energy and would result in stronger markers, but this doesn't seem to always be the case.

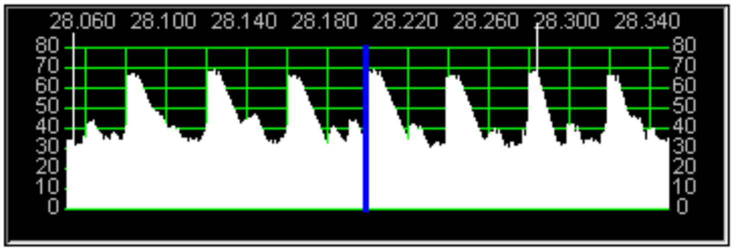



Next, the pulse generator circuit was adapted for the VE3DNL marker generator. Since the VE3DNL can work directly off a 9V battery or a 12V power supply, a 5V regulator would be needed if the 74HC132 circuit was used. This would be inconvenient - so a 4000 series CMOS NAND gate with hysteresis, the 4093 was pulled from the junkbox. Since the R1 and C1 of the previous circuit are omitted, a 4011 NAND without hysteresis should work as well. With the circuit above, pulses roughly 50 ns in width are created on the rising edge of the VE3DNL marker output. These pulses have much longer rise and fall times than the 74HC132 but that doesn't seem to affect the performance of the circuit that much.




Spectrum of VE3DNL markers on 10 meters 40 KHz - 50% sq. wave

Here is the "before" picture - a spectrum display from the RX-320 on 10 meters of the 40 Khz output of the VE3DNL marker generator (50% duty cycle square wave output). It shows the characteristic up and down amplitudes between the even and odd harmonics.




Spectrum of VE3DNL markers on 10 meters 40 KHz - 50 ns pulse

Here is the “after” picture, the 4093 pulse generator has been connected to the 40 Khz output of the VE3DNL marker generator. The RX-320 spectrum on 10 meters shows the uniform amplitude expected for the pulse markers.

Conclusions:

I’ll certainly be doing some more investigation on the pulse generator circuit. The spectrum should be checked on other bands. The variation of the RX-320 amplitude spectrum plots should be isolated. Also, other logic families and parts should be tried in place of the 74HC132. The moral of the story - there’s lots of interesting talk on the QRP-L email list - keep your eyes open!

Chuck, WB9KZY

Notes:
1) The VE3DNL marker generator design was presented in a QRP-L email from 7/20/95. This email can be seen on the web at:

http://wb9kzy.com/ve3dnl.htm

The VE3DNL kit is currently available from Jackson Harbor Press as of August 4, 2023

2) The RX-320 is a computer controlled receiver from Ten-Tec. The windows control software for the RX-320 has a nice spectrum sweep display. I used the print screen function in windows to capture these displays to disk. The vertical axis of the display is simply the S-meter reading (a relative reading in db), which has been recorded by the program as the receiver is tuned through the range on the horizontal axis.

3) QRP-L email dated 10/14/99 from Nick, WA5BDU, subject: TT2 & 2nd harmonic

4) QRL-L email dated 10/22/99 from John, KU4AF, subject: RE:crystal calibrator

5) "A Frequency and Level Standard" by Hans Evers, PA0CX, from January 1986 Ham Radio magazine - (mentioned by John, KU4AF)

6) The operation of the narrow pulse generator circuit using the 74HC132 will be explained here. This circuit is basically a glitch creator which takes advantage of the

propagation delays inherent in all digital logic. The circuit uses a NAND IC which has 4 separate 2 input NAND gates. The truth table of the NAND gate is presented here:

| A input | B input | Y (output) |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

The 0 and 1 represent voltages of 0 and the power supply voltage of the IC. If the inputs are tied together, the NAND gate functions as an inverter (a zero input provides a 1 output). Armed with this background, the functioning of the circuit can be explored.

The marker generator provides a square wave, at 100 Khz this is 5 microseconds of a logic 1 followed by 5 microseconds of a logic 0. So if we assume that the marker is now at a logic 0, pin 1 of U2 is also at 0. Pin 2 of U2 is a logic 1 since U2B acts to invert the marker output. The output of U2A (pin 3) is a logic 1 from the table. U2C inverts this to a logic 0. Then the marker generator output changes to a logic 1. Pin 1 of U2A is now a logic 1 BUT pin 2 of U2A remains at a logic 1 because it takes time (propagation delay) for U2B to invert the marker generator output. This means that U2A output will change to a logic 0. This is then inverted through U2C to a logic 1. Eventually, (10 to 50 nanoseconds later) U2B will invert the marker generator output - the output of U2A will then change back to a logic 1 and be inverted by U2. As the marker generator output finally changes back to a logic 0, U2A pin 1 will be a zero, so the U2A output will remain a 1 no matter what state U2A pin 2 is in. The output of the generator will stay at a logic 0. Here is a table summarizing these transitions:

| marker generator output | U2A pin 1 (input) | U2A pin 2 (input) | U2A pin 3 (output) | pulse generator output (U2C pin 8) |
|---|---|---|---|---|
| 0 | 0 | 1 | 1 | 0 |
| 1 | 1 | 1 | 0 | 1 |
| 1 | 1 | 0 | 1 | 0 |
| 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 1 | 0 |

Note that R1 and C1 can be used to extend the pulse width to hundreds of nanoseconds by delaying the logic transitions through charging and discharging of the capacitor through the resistor. Using a NAND gate with hysteresis inputs will avoid oscillations as the voltage at the output of the RC filter slowly moves through the switching point (roughly 2.5 volts) of the NAND gate. If R1 is eliminated, a regular NAND gate such as the 74HC00 or 4011 will work as well as the hysteresis NANDs such as the HC132.