# WWVB de-PSK-r

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Written by: Paul Wb8-tsl

## Preface

This system is highly experimental and is not in any way intended to be an absolute design or a kit. I have used parts from the "Drawers". So these may or may not be optimal. There are only 2 real parts that did not come from the drawers. The mouser IF transformers and the 60 Khz crystal, called out. Though all of it works every stage could be characterized and optimized for better performance. But the fact is this design does allow a wide range of the old phase tracking receivers to work. It does not require modification to any receiver and is a general purpose solution.

I have spent a solid year pretty aggressively on this set of projects with many many alternates tried and rejected. One person on the time nuts group has responded to my weekly emails on this and that. Thanks to him. Happy to share his contact information but that will be up to him.

## Introduction

This document covers an approach to remove the WWVB PSK signal such that traditional phase dependent receivers will work again. With the direct output the following receivers have been tested and do work and were driven from the 60Khz output.

Dymec  5842, Fluke 207, HP VLF 117, Spectracom 8163, Tracor 599.

The spectracom 8170 AM time receiver requires the AM phase flipper.

More on phase flippers later.

The solution really consists of 2 major parts a TRF receiver and a classic Costas loop described by CA Habst  in 1970. This costas loop is very simple, but did work right off the bat. The article didn't really go into any detail on filters or such it was a general discussion. But as it turns out quite good.

The TRF receiver is very traditional takes 1 uv and brings it up through some filters and a Xtal to establish the receiver bandwidth of about 10 Hz. Does have AGC control and includes a soft limiter ti remove the WWVB AM component for phasing receivers.

The Costas loop can be used completely independently of the receiver. It could be inserted into a receivers chain as an example. Though generally AGC becomes a problem. The same can also be said of the receiver if your interest is in a frontend to some other process.

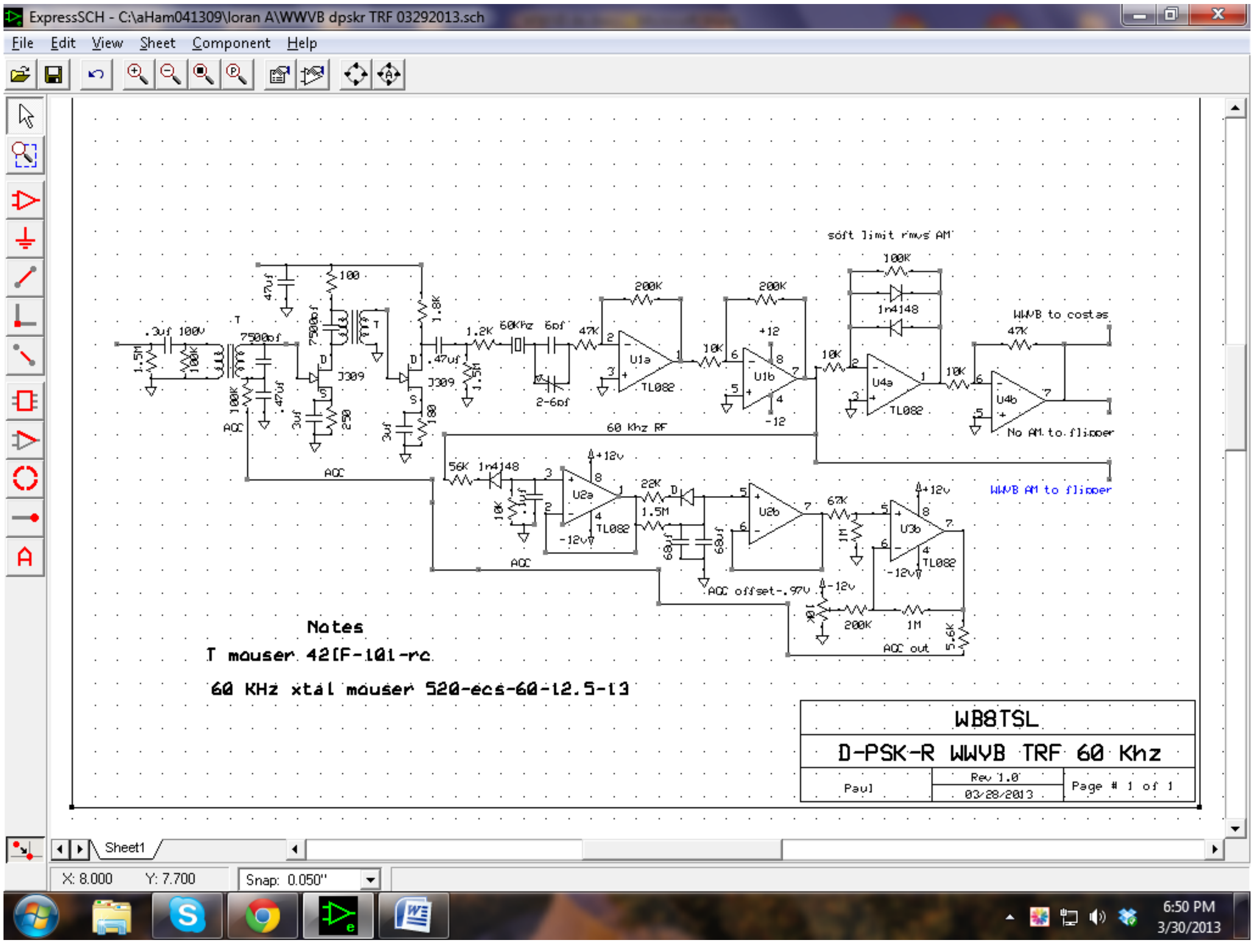
I looked at and built numbers of TRF units from the web some were fine but used obsolete components others were for reasonably strong signals. Nothing really wrong with them. Even tried a single chip MSA8160 receiver simply no way to tease out the 60 KHz. The chips quite attractive the chips are still available. It covered agc, the xtal filter, gain and is hot at .4uv. As I say no reasonable way to get the 60 Khz. (Still not giving up on it actually)

So these 2 circuits do work and can be made better in filtering damping, time constants, and design. But its nice to see the old receivers work. I have run this system for longer then a week and though it is winter it does stayed locked. It does have trouble with MSF when its strong at night. But not that often an issue. I am near Boston so MSF and WWVB are equidistant.

Flipper comment. One of the outputs that can be obtained from the costas loop is the new PSK data. This also represents the signal phase 0 or 180 degrees of the wwvb carrier. By itself it can not determine absolute phase. It depends on how the VCO locks and that can be 180 degrees in error. This is true of all of the costas loops I looked at. In order to make the old time receivers like the spectracom 8170 work you would run the AGC controlled signal into an inverting or non inverting amplifier so that the phase is corrected but the AM modulation stays intact. Many ways exist to accomplish this. As anexample a opamp and cmos switch. Multiplier and other approaches those are not a part of this effort. Further if you absolutely want a direct WWVB signal take the limited no AM signal and pass it through a flipper. That’s a clean consistent wwvb signal. Neither are included in the schematics.

Power is plus 12 V @ 80 ma and minus 12 @ 20 ma. The digital circuits use 5 V from the +12 and are most of the actual current of the plus 12. A LM78L05 creates this supply. Bypass caps are sprinkled throughout and not all are shown in the diagrams.

## Schematic of the TRF receiver.




The signal comes into the drawing at the left. I have not added an inductor for power and bypass cap. Those are typically different for various receivers/preamps. My receiver gets a signal from a wwvb multi-coupler. The signal hits a 455Khz IF transformer resonated at 60 Khz approx with a 7500pf SM cap. In parallel with the internal 180pf cap always. These were the only IF transformers available from mouser at the time. This then goes to a J309 N channel FET that is also controlled by AGC. During testing I discovered I needed some additional gain in the chain and I added a second J309 FET. In this area when you see a 1.5M resistor to ground they are being used as standoffs only. From the second FET the signal goes to the 60 KHZ crystal that is tuned by the variable and fixed cap. Several op amp add gain of 5X and 20X respectively. Though TL072 Op-amps are used there are far better ones to consider. This delivers a signal at the output of IC1b that is used for 3 different purposes. WWVB AM out to a flipper, WWVB for AGC control, WWVB to the soft limiter for the costas loop or other methods.

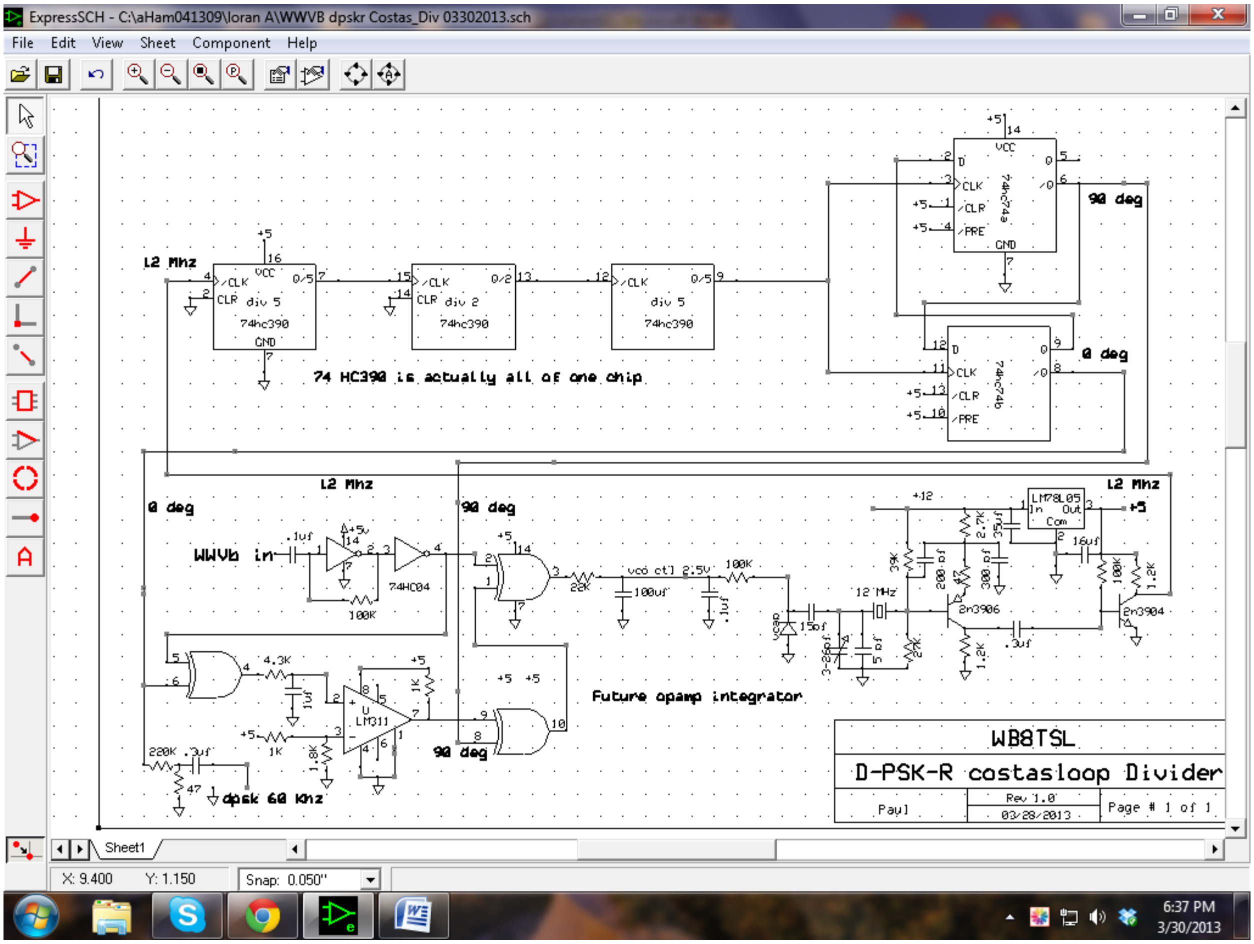
The WWVB AM out is simply a AGC controlled signal that is intended for use with Timing receivers that use phase tracking carrier recovery to generate the old style timecode. Through a flipper this the signal needed for receivers like the spectracom 8170 and I believe the truetime DC60.

The second output goes to IC2a and is a simple AGC system. Its time constants long around several minutes and is intended to deal with the slow changes that WWVB experiences with propagation. Setting the pot to -.97vdc seems to set the offset AGC range into a reasonable behavior.  The output feeds back to the first stage to control over all system gain.

The soft limiter. Goal is to remove the 14db of AM modulation on the WWVB signal. A hard limiter was tried but when the signal faded to 0 noise was introduced. The 100K resistor creates the soft limiting action.

The output of the limier goes to a 5X opamp and presents 2 VPP limited wwvb carrier. This feeds the digital costas loop and a second output could go to the left over 7486 section in the costas loop for a corrected limited carrier out to receivers.

## Digital Costas loop




### Costas loop description

The digital costas loop is the real heart of the d-psk-r. The costas loop is made of the following circuits. A 12 Mhz VCO, Divider chain, Two phase detectors, a selectable phase inverter, Integrators.

Starting at the lower left the WWVB signal from the TRF receiver is increased and squared to a 5 volt logic level and feeds into two phase detectors PD made of a 74HC86 sections Pins 1and 2 is the sine or 0 degree VCO voltage PD1. Pins 5 and 6 are the cosine 90 degree PD2 to determine incoming phase relative to the local 12Mhz reference.

PD2 evaluates the phase compared to the local reference and after being filtered for noise is the phase transition between 0 and 180 degrees. The 1 uf at 50V is reasonable but I do wonder if a .47 or .2 might work as well or better to minimize the transition period. 50V caps are used for lower leakage. The LM311 simply decodes on the phase reversal and squares this signal up. This phase flip signal represents the new WWVB digital data. This signal could also go to the AM phase flipper for timing receivers.

Though these phase detectors are simple exclusive Ors they do work well. I do believe CD 4046s would be better. But that's a someday maybe.

The output of PD2 goes to the 3rd section of the 7486 pins 9-8 and invert the 90 degree signal or not to feed PD1 to correct the local reference to wwvb. This allows the output of PD1 to be integrated for VCO control.

Integration is very simple and simply OK. Note no damping. No opamp… this area needs help.

The tough part is what should the integration constants be. I am guessing. Had used a 474K and 1M and the TC was far to long with excessive hunting. 22K is pretty aggressive. Damping will add a further dimension. But these are reasonable to calculate if you have a known starting point.

The output of the integrator goes to the 12 Mhz VCO

**12 MHz VCO**

Lots of different VCO and divider topologies could be used. The result needs to be a clean sine and cosine signal. I used real L+C arrangements, opamp delays and finally the digital approach for this solution. All work. (I know someone insisted on this early on) The VCO is simple and uses a 12 MHz crystal. All of the bias and output are pretty insensitive to component variation. However on the left side of the crystal things that tune do become sensitive. The Vaiable cap sets gross frequency and the 15pf cap sets how much effect the varicap has on the system. The HEP R2025 is a 56pf Vcap. I even used zener diodes as varicaps as suggested in time nuts they do work quite well but I was concerned on tempco drift. I will say they are very available just that they aren't very characterized for this application.

This particular Vcap was in the drawer and can't be obtained. However there are quite a few Vcaps at mouser and digikey. Most likely there is a great substitute. Note also I have not introduced an offset pot in the circuit. When I work on an opamp integrator I will add that in to see if that allows for a wider range of components. All caps are silver mica in the oscillator section.

Though this design works it's a bit hard to document how to set it up. I adjust the 3-26PF cap for center freq with 2.5V on the Vcap and matching a local 12 MHz reference. This has to be very slow in drift.

This 12 MHz VCO really could use the help of some standard simple low tuning low drift dip oscillator. The circuit tunes as .5V=.1 Hz at 12 MHz. Most likely the dip chips have to wide of a range and stability may not be good enough. Its been suggested to look at ebay. But that's not really a general solution and there is never enough detail to figure much out. It's a gamble.

Then hook up the PD1 output after several minutes it should lock. But what almost always happens is that over night it lets loose. I drop the room to 56 at night. In the morning a gentle tweak relocks the system and from then on it seems to work fine. That's sort of magic not science and I dislike that approach a lot.

## Divider chain

This is a classic chain using a 74HC390 dual divide by 10 to 240 KHz and then a 74HC74 to develop the 60 KHz sine and cosine signals. Express PC does not have a 74HC390 and in the past creating a symbol is a bit of a pain. So I created my own and it does contain the information needed to actually wire up the chain.

## Conclusion

The system works and is simple. It is not the absolute or best design. I could go on for another year tinkering and to some extent will. But for now this does get the old receivers back online with parts that are generally available and inexpensive.  All of this design used stuff from all over the internet, my paper archives, and experimentation. You are welcome to do anything with it and modify it anyway that you would like.

I have pictures of the components but they are actually pretty large at 2 MB. So did not put those or the phase comparison charts in this document.

I will be happy to answer emails to an extent that time permits and that I really have any answer. But as pointed out on time-nuts I would like to limit this to 90 days from 1 April 2013. I will not be able to create kits or PC boards nor supply parts. I am not a business, just a time-nut.

## Final comments of interest.

Other costas loop approaches built MC1496 far to complex many resistors but cheap. The Analog devices AD633 costas loops. This one deserves continued work especially with the knowledge gained from the 7486 costas loop above. Other VCO and divider chains using a vectron 9.6 Mhz vco. Stability and tuning range.

Next area of interest is a digital approach very clearly this is a phase memory with comparison method and now that I have a reliable frontend to work makes this even more interesting.

But this simple approach most likely pales in comparison to what might be done with DSP. SpectrumLab gives clues to this area. I have tinkered with it on WWVB already. But that's a whole PC and sound card… Some of the weak signal amateur work gives further clues like WOLF. Whats great about WWVB is it's a 1Hz data change rate.

Good luck.