

# Hot Iron

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Spring 2016

Issue E91

## Editorial

At last the days are getting longer and there is less temptation to spend time huddled over some inside project because the weather is poor or it is dark outside! As a farmer, we also tend to notice that our grass is beginning to grow again – both in the field and on our lawn – in fact it has hardly stopped growing this winter and I ought to be getting the mower out right now! All of which suggests its time to be thinking about outside radio projects – most probably something to do with aerials!

For many years I have had a half wave dipole for 160m centre fed by open wire line but one support was carried away by the wind this winter, so I have been temporarily using a different half wave dipole for near 7 MHz inside the roof, fed by what the telephone fitters in the UK call ‘drop wire’, this is a high tensile copper pair in a figure of 8 plastic coating which is a fair match to the low impedance centre of a dipole. While not the best of aerials, it does have the benefit that if a new receiver can hear the atmospheric static using this dipole, then the RX does have enough sensitivity and there is no need for anything better – a lower noise front end with a bit more gain will still only hear the band noise even with a better aerial! About the only case for improving the sensitivity is for applications where a ‘normal’ full size aerial cannot be accommodated thus requiring a smaller aerial that would normally also hear less noise! (If space is really tight, I prefer a magnetic loop – these can be quite simple malleable copper tubes in either single or multi-turn form, or even multi conductor mains fixed installation cables (only suitable for the LF bands due to high capacity between cores) – feeding the loop RF can also use a gamma match tap part way round, instead of the fiddly small feed loops that are often suggested for the feed mechanism! No need for AMU either!)

But back to my downed external dipole! For various reasons, I am not allowed to replace it and must erect something in an alternative location with a span of up to about 100 ft (30m) but it has to be end (or near end) fed! I want multi-band operation so contemplate an open wire end fed Zepp of 66 ft but my ‘electronic theory’ really does not like that single unconnected feed wire where the other side of the feeder joins the half wave! Where does the RF ‘in that open circuit’ go?! I would much prefer a balanced scheme and I have the feeling that the open wire feeder of a traditional Zepp contributes very little – I fancy you might just as well run the single aerial conductor all the way to a capable Aerial Matching Unit that tune out any reactance and can be mounted near the operating position, with a decent RF earth spike/mat or multiple counterpoises!

I am sure that amongst us, we have a reader with more relevant knowledge on this subject than me, so please come forward and tell us what I should erect! Tim G3PCJ

**Contents** Kit developments, Out of the Dark Ages, Reflex Receivers, Local Oscillator schemes for Superhets, Big Bad Wolf (drift), Gaining confidence to Homebrew, Snippets.

**Hot Iron** is published by Tim Walford G3PCJ of Walford Electronics Ltd. for members of the Construction Club. It is a quarterly newsletter, distributed by e mail, and is free to those who have asked for it. Just let me know you would like it by e mailing me at [electronics@walfords.net](mailto:electronics@walfords.net)

## **Kit Developments**

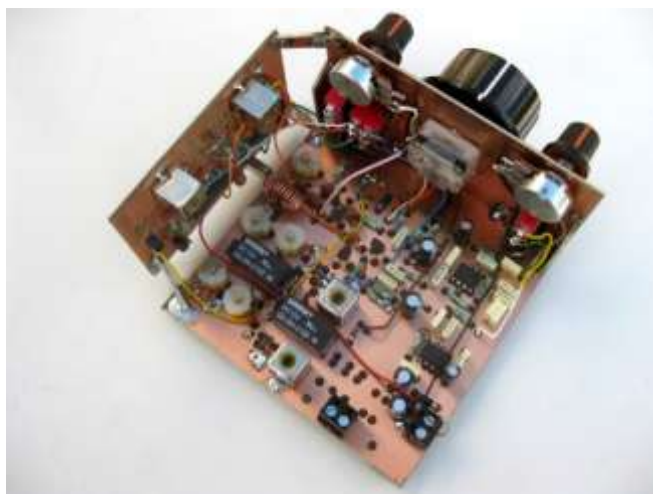
It has been another busy few months; not long after I had completed the design of the Rumwell, I realised that it was not simple enough for complete newcomers – the hand wired crude prototype seen in the last issue has since become the Rodway after discussions with Steve Hartley G0FUUV and the RSGB about projects for schools. It uses a PCB laid out by the RSGB (on right) with three BS170 transistors in a plain TRF arrangement. It has two bands – the HF end of the Medium Wave band with its powerful broadcasting stations for an early build and easy ‘success’, and also 160m for an intro to amateur radio. I am expecting to be able to offer the RSGB version for sale soon.



I have begun work on the Redlynch RX (early version right) which is a derivative of the Rodway but with a Regen stage added (another BS170) so that it is able to copy CW and SSB as well as AM. It is intended as a broader introduction to amateur activity so it has all four bands 40, 80, 160 and Medium wave! It too uses a 9 volt PP3 battery and modern 32R phones but is laid out on a 100 x 160 mm PCB for plenty of space. This can also be used with the AM phone Rimpton TX (see last Hot Iron) which can do any one of 40, 80 or 160m with a peak Pout of 1.5W AM, or also on CW!



The last project nearing completion is the Mk 2 version of the Yeo DC receiver. This starts life as an ‘any single band’ of the 20 - 80m group but has the ability to add two bands to make it into a 20, 40 and 80m RX. This is aimed at use with the Mk 2 Mini mix kit with its 3 band LO outputs, where the Yeo’s VFO is altered to run at 5 MHz to mix with the 9 MHz crystal for 14 MHz and divided down lower bands (on right). It has audio output for a low Z speaker or phones with a switched humped low pass filter for CW centred on 725 Hz. The Fine tuning control can be ‘centred’ automatically by the Isle transmitter when used for CW. This early model has the Mini mix kit attached by PCB strips on the side. G3PCJ



## **Out of the Dark Ages** by Pete Juliano N6QW - radioguy@hotmail.com

Yes, we are talking about The Dark Ages or it would seem so, if someone were to suggest using Dual Gate MOSFETs in a new radio design. Hello, Dark Ages when one thinks about that undoubtedly right at this moment, there is a 10 year old school boy (or girl) that received a \$5 Raspberry Pi Zero as a Christmas present.

With that device and using only two capacitors and one single coil, that youngster has fashioned a fully functional SDR transceiver. It was a simple matter using Python to create, in software, two Hilbert transforms, add in an image cancelling summer, create a couple of digital filters for SSB and CW, and finally add in a couple of IQ detectors. Oh lest we forget the waterfall display that uses parts from a defunct cell phone. Along the way he or she added an S Meter and fast attack AGC circuit. The really sad part for me was all that was done during a 15 minute school recess break. The \$5 SDR transceiver is alive and walks amongst us! In today's radios there are few wires and it is mostly software wherein radios from the Dark Ages –it was all wires and discrete components!

One problem today in using Dual Gate MOSFET's in our projects is that the old standard "leaded devices" such as the RCA 40673 Dual Gate MOSFET are nearly un-obtainable or cost an arm or leg, if you are lucky enough to find one. Virtually every ham radio project in the 1970's and early 1980's started with an RCA 40673. Who can forget Hanchett's 40673 VFO that graced the pages of QST which became the standard for VFO's? Or consider the project books from ARRL authored by Doug DeMaw or Wes Hayward that had a DGM in literally every circuit.

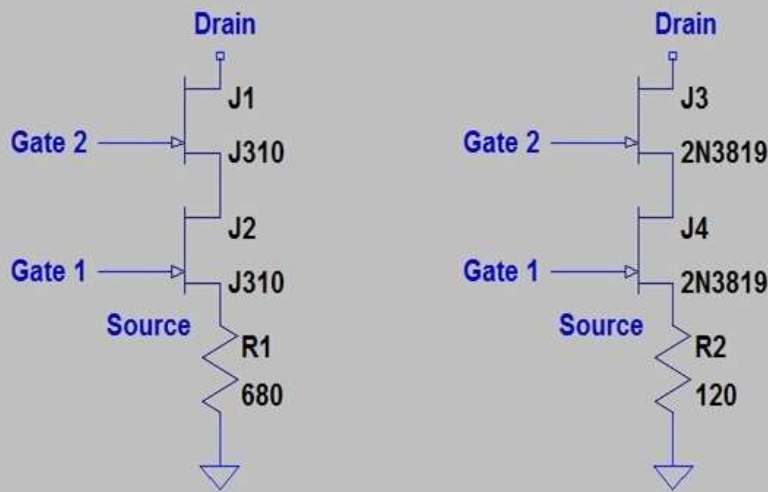
Today there are many Dual Gate MOSFETs (DGM) now available in the Surface Mount packaging at a fairly low cost. One good example is the NXP Phillips BF991 that costs roughly around 50 cents in single lots. This DGM is good to 200 MHz and can operate easily on 13.8 VDC. Of course surface mount for many homebrewer's is like climbing Mount Everest in Bermuda shorts and flip flops (a standard California Uniform of the Day). Hang on for in a short while we have a solution for you.

I am often asked why do you like Dual Gate MOSFETs and before I can answer, I usually hear "well you know they are subject to overload and they have noise figure problems and on and on". My answer is that DGM's can be configured as an Oscillator, Mixer, Amplifier, or even as a Product Detector. In fact they can be "gain controlled" by either manually or automatically changing the voltage on Gate #2 – we are talking AGC here! So there are many positive aspects for using such devices.

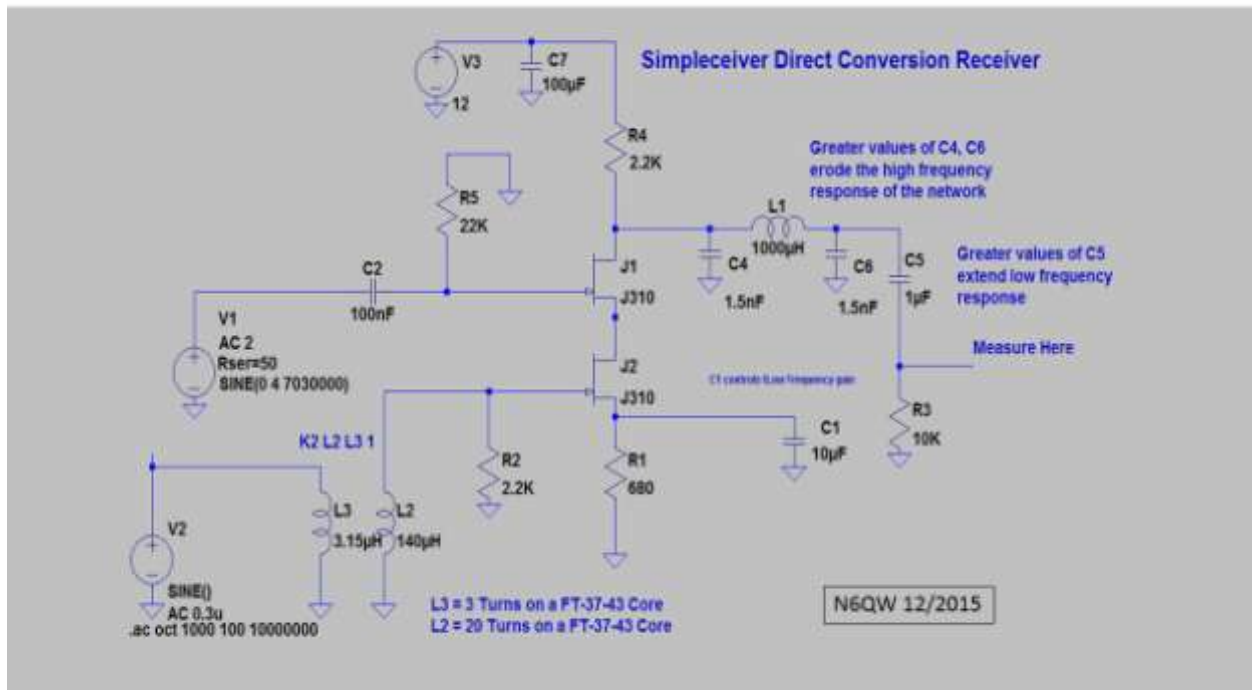
Now the solution –why not scratch build a Dual Gate MOSFET from commonly available leaded parts. If we were to connect two JFETS such as the 2N3819 or the J310 in the cascode configuration – instant Dual Gate MOSFET. Essentially cascode has the Source of one JFET connected to the Drain of the second device. Shown below are two popular JFETS that have been employed in our projects. But note that the Source resistors are different based on the individual differences of the devices. The J310's require a higher Bias level.

The bonus -- you get the benefit of Gate #2 such as in the case of a Direct Conversion Receiver, where the LO is injected into Gate 2 and the antenna with suitable matching is applied to Gate #1. In the case where the pair is used as a Product Detector then the BFO is injected into Gate #2 and the signal from the IF, with appropriate matching is fed to Gate #1. You get the idea.

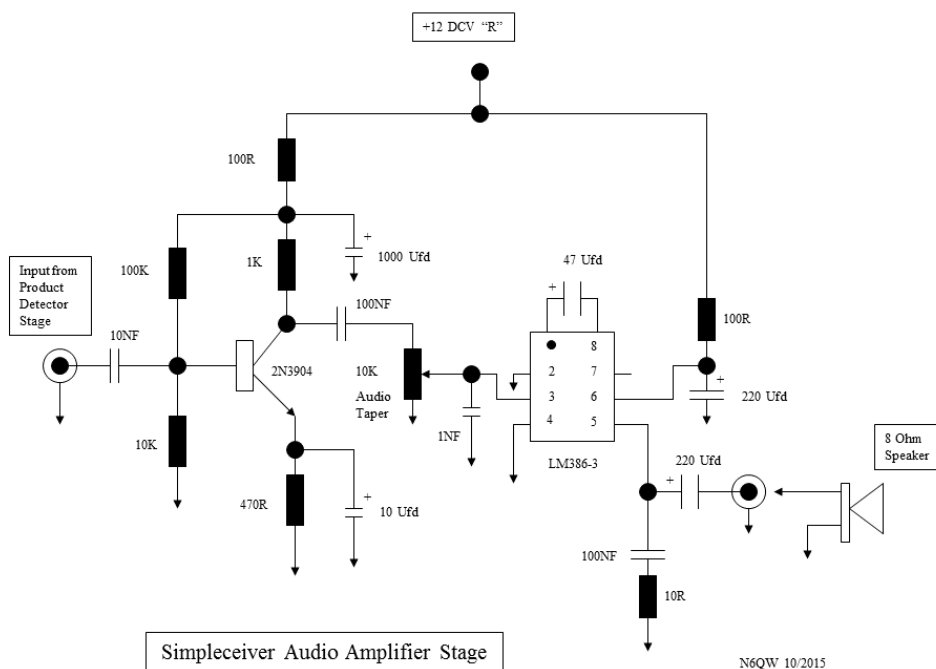
### JFET's Configured as Dual Gate MOSFETs



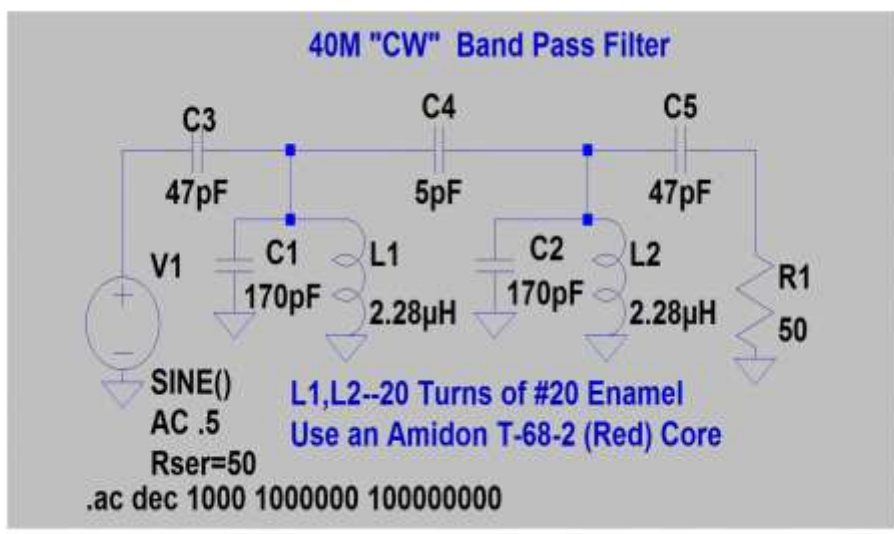
Here is a design for a Simple Direct Conversion Receiver element using either the J310's or the 2N3819's. The design below is direct from the LT Spice Simulation which I encourage the readers to use for evaluation purposes. You will see about a 20 dB gain over the audio spectrum. The LO has about 2 Volts Peak to Peak (10 dBm) and the Zin is 50 Ohms. For the 2N3819 the only change needed is the Source resistor is 120 Ohms versus the 680.



This Direct Conversion receiver is followed by audio amp employing a 2N3904 driving an LM-386-3 as shown below. I have built discrete component audio amplifiers but I consider that approach pre-dark ages.



Ahead of the DCR module would be the Band Pass Filter that has been peaked up for 40M CW. This is the LT Spice Simulation and R1 is not used in the physical build.



It may be necessary to add a bit of RF amplification ahead of the Band Pass Filter and the Internet abounds with many circuits. I say this because one builder was using a rain gutter for an antenna, only he didn't realize the gutters were plastic material and so he only had about 10 feet of wire for the antenna. The RF amp helped out – a lot.

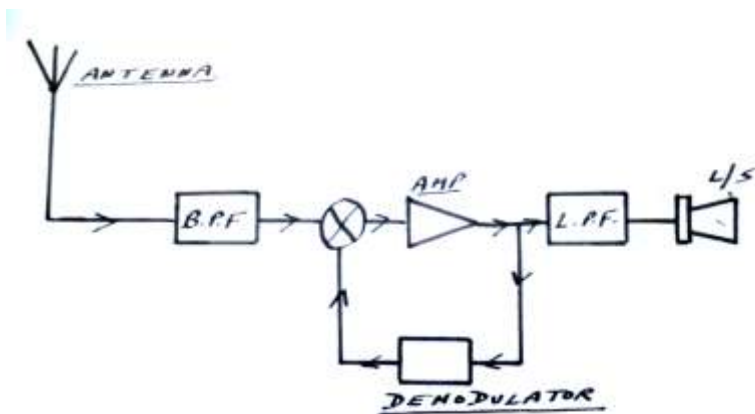
So OK no one asked why the young lad or young lady needed the two caps and the coil for the Pi Zero? [Drum roll please!] For the young of today, it is the “cool factor” – you have to have something that you can point to and say “Isn't that cool?” Dark Ages also has a further definition: anyone who watched the moon landings in 1969, as an adult, (like me) is from the Dark Ages.

73's Pete N6QW (Request by G3PCJ – would that 10 yr old please come forward and offer me a short layman's guide for Hot Iron on the Hilbert transform?)

## **REFLEX RADIO RECEIVERS** by Keith Woodward G6AAZ

My earliest memory of homebrew construction was to build a Reflex ( or Reflectional) radio receiver from a design in "Radio Constructor". Some 50 years later having built many of Tim's kits the thought occurred to me as to why are such receivers are not as popular as other designs (i.e. Crystal, TRF, Regenerative, DC or Superhet)? Then I realised that I did not know how a Reflex receiver worked so I found out and hence this article.

The Reflex receiver dates back to 1917 and it works on the principle of using the same amplifier for both the radio (R.F.) and audio ( A.F. ) signals. The R.F. from the antenna and tuned circuit passes through Band Pass Filter ( which act together in a similar way to a T.R.F. circuit ) before passing through the amplifier. The signal is then routed through a High Pass Filter before going to a demodulator which extracts the A.F. signal from the R.F. carrier. Next A.F. signal passes through the same amplifier before passing through a L.P.F. before reaching either an earphone or loudspeaker. The design uses the "superposition principle" i.e. if the amplifier is linear then 2 signals of different frequencies passing through it can be separated at the output using suitable filters.



**REFLEX RECEIVER.**

The main design objective was to reduce the number of active devices at a time when they were very expensive. To put it another

way the Reflex receiver uses half the number of active devices when compared to other receivers of its era. In the 1920's it was used in inexpensive vacuum tube radios and in the 1930's in simple portable vacuum tube radios. However the design was vulnerable parasitic oscillation if the design of the amplifier was either not linear or was operated outside its linear range.

So the challenge is, can anyone design a reliable receiver for amateur radio purposes working on the reflex principle. Any body wish to offer a design?

*Comment by G3PCJ* The reason that nobody uses this approach, in modern 'commercial' designs, are the obvious ones that Keith mentions! He alludes to the compromises that have to be made in order to make a viable design; the consequence is that probably some aspect of performance is not as good as if that functional block had been designed just for a single purpose! The other important difference is that years ago valves were very expensive compared to the other parts and hence there was a very strong incentive to make them 'work' as much as possible – transistors are now so cheap that they can be thrown in almost without consideration of their cost! BS170 MOSFETs in quantity are just a few pence each but it is the mechanical items that are now unduly expensive – e.g. tuning capacitors and knobs – I cant immediately think how to get multiple uses out of them?!

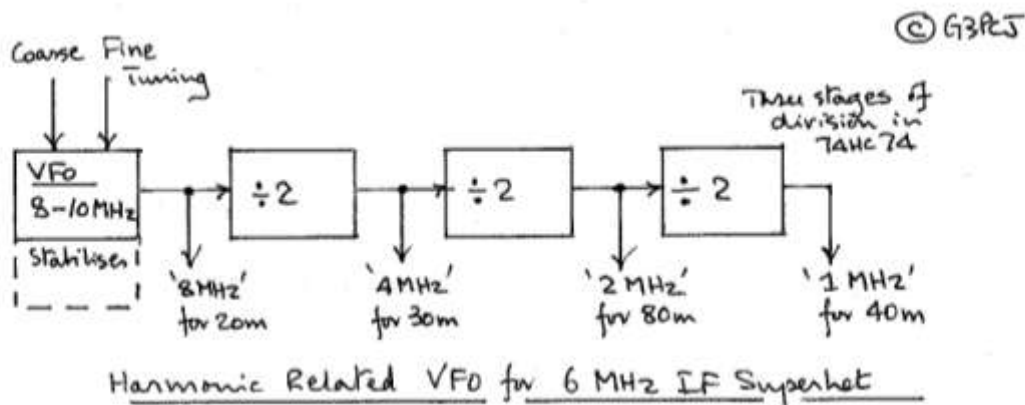
## Local Oscillator Schemes for Superhets

I am always doodling over alternative 'analogue' (not DDS!) frequency schemes for new rig possibilities – here is another! I have used an Intermediate Frequency of 6 MHz very successfully in many rigs and see few reasons to depart from that! It makes sideband switching, and simple frequency counter designs, much easier! The bands of most interest are those in the group 20 to 80m because some, or all of them, are what most customers usually desire.

The table below shows the local oscillator (LO) frequencies that could be used for additive or subtractive mixing in the superhet's first mixer, based on a 6 MHz IF:-

<b>Band</b>	<b>Freq range MHz</b>	<b>Additive Mix LO range MHz for 6 MHz IF</b>	<b>Subtractive Mix LO range MHz for 6 MHz IF</b>	<b>VFO division factor</b>	<b>VFO range MHz</b>
20m	14.0 - 14.35	20 – 20.35	8.0 – 8.35	1	8.0 – 8.35
30m	10.1 – 10.15	16.1 – 16.15	4.1 – 4.15	2	8.2 – 8.30
40m	7.0 – 7.2	13.0 – 13.2	1.0 – 1.2	8	8.0 – 9.6
80m	3.5 – 3.8+	9.5 – 9.8+	2.5 – 2.2 - Backwards	4	10 – 8.8

It is obvious that the LOs of the subtractive mix are all harmonically related or very nearly so - hence digital division becomes an interesting possibility! With the VFO running near 8 MHz, three stages of division by two can provide the LO for any or all the desired bands!



There are some drawbacks – firstly, the VFO has to tune from 8 to 9.6 MHz to cover all of 40m (or to 10 MHz for the US 75m band) – this is a bit large for comfort - but its not impossible if one uses a combination of Coarse and Fine (or band set and band spread) controls. The other aspect is that the tuning rate of both controls will vary from band to band – this might be a little disturbing at first but the simplicity of digital division, which avoids the need for crystal mixing and LO band pass filters, is a huge cost, complexity and reduced risk benefit. CIO sideband switching is needed but is not difficult! Stability of an 8 to 10 MHz oscillator might be questioned but if it were stabilised with a Huff and Puff scheme (see next page!) that should not present a problem either. If the superhet is also to do CW, then provided this is done by the injection of a keyed 750 Hz tone, then the LO frequency does not have to change between reception and transmission in order to get both stations on the same frequency! G3PCJ

## **The Big Bad Wolf (drift)**.... by Peter Thornton

In L/C oscillators the wolf is *drift*. You can use whatever configuration you want, L/C oscillators will drift with temperature, time, power supply variation, orientation (with regard to other components) and a dozen other effects that make an L/C oscillator not an easy choice, despite the great advantage of simplicity plus few components. You can eliminate drift to a certain extent; add positive and negative temperature co-efficient capacitors for instance, use a Clapp or Vackar configuration (though for my money you have to try very hard to beat a Butler, either fundamental or overtone), or you can use an *oscillator stabiliser*.

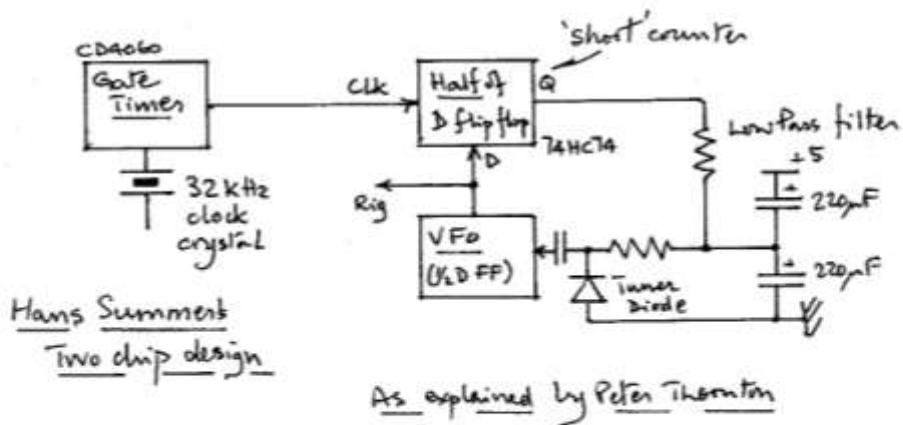
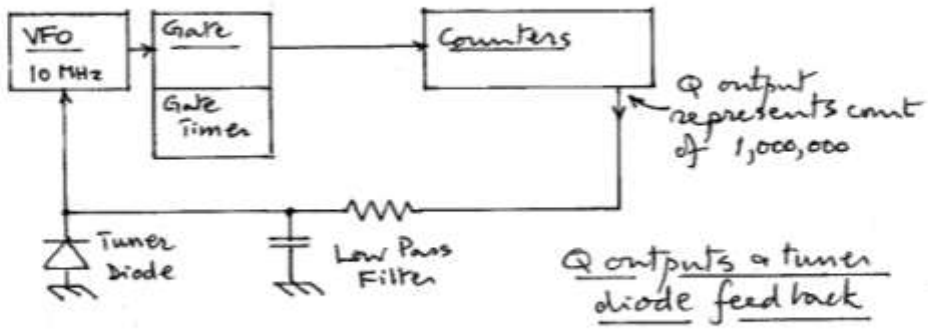
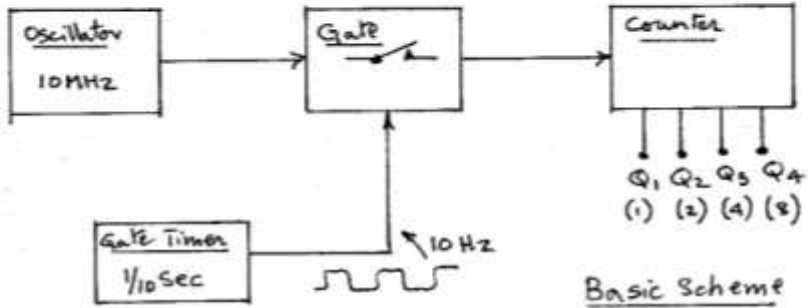
Commonly known as “Huff & Puff” stabilisers, these add-on digital systems give an L/C oscillator the stability of a synthesizer; they tune in a series of frequency steps, the step size determined by the timing of the digital system. Huff & Puff stabilisers were first outlined in the 1969 by Peter Martin, G3PDM, and implemented practically by Klaas Spaargaren PA0KSB in 1973, as reported by Pat Hawker G3VA in his “Technical Topics”. The principle is this: count the oscillator cycles (cycles per second = frequency = Hertz) for an accurately defined time; check if the count is more or less than the desired frequency; apply a “correction” to the oscillator. Thus, the oscillator frequency is controlled and defined by the accuracy of the count time - in commercial frequency counters, this is called the “gate” time. Here's an illustration. Our variable frequency oscillator is of reasonable construction and design, and is running at 10MHz. The gate time is set to 1/10th of a second, so the counter will accumulate a count of 1,000,000 in 1/10th of a second, as in top diagram on next page. I have only shown a single counter chip for convenience (many more can be strung together for bigger counts) and illustrated the gate as a switch. Reset lines, power, etc. are not shown for clarity.

Now consider the VFO drifts LOW - in 1/10<sup>th</sup> of a second, the count might only be 999,900; if the VFO drifts HIGH; the count might be 1,000,100. Part of the capacitance in our L/C VFO is the tuner diode, if the VFO drifts LOW, we need to increase the bias on the tuner diode; if the VFO drifts HIGH, we need to decrease the bias on the tuner diode. If we observe a “Q” output (in second diagram,) that represents the “1,000,000 stage”, and that Q is logic “0” after 1/10<sup>th</sup> of a second we know the count is LOW; then if the “Q” is logic “1” the count is HIGH. The “Q” output, representing a count of 1,000,000, is inverted, and then used to adjust the bias on the tuner diode, the counter will correct the drift of the VFO, to maintain the count to be *exactly* 1,000,000. That's Huff-N-Puff, as in middle diagram! You can scale the frequency, gate timing and Q output to suit any frequency.

It would appear that you would need strings of decade counters to accumulate the numbers, and special gate timing for the scheme to be successful; but in reality you can simplify the whole thing to a couple of logic chips! You don't actually need all the in between stages of the ‘measuring’ counter & instead use just a short version consisting of a single flip-flop. The simplest design I've ever used is in the bottom diagram, which is from Hans Summer's design at [www.hanssummers.com](http://www.hanssummers.com) in the “Other Radio Topics” section. The gate timing is done with a 32kHz watch crystal plus a CD4060 chip, the Huff-N-Puff “counting” is done by one half of a 74HC74 dual D flip-flop. Hans uses the other half of the dual D flip-flop as an inverter for the VFO oscillator! You can easily adapt Hans' design to suit; 74HC logic is fine to 50MHz, and if you really want to push the limits, Potato Semiconductor (yes, check them on the internet!) make 74HC pin compatible logic chips that run to 1GHz.



# HUFF-N-PUFF!



## **Gaining the confidence to home-brew** - by Dick N4HAY

I have been a committed QRP'er for many years and over this time I have built and operated a number of QRP kits. My biggest and most complex kit was the Elecraft K2. Much as I love to operate these rigs I have always had a yearning to really understand and participate in 'The Radio Art'. How does that radio really work? I wanted to be a radio design engineer from a very early age. So much so, that I attended university and obtained an electrical and electronic engineering degree. However this led me down a professional career path far removed from my starting goal. Life has a tendency to get in the way, of course. In my early years I never did get to really understand how radio worked - certainly not a practical, deep and real understanding. So how might one go about acquiring this knowledge?

For me it was not until 3 years ago when I was working in South Africa that I really started to make meaningful progress towards my original goal. I was travelling a lot in my job. These long flights gave me the opportunity to study the classic QRP books. After absorbing Doug De Maw's books (W1FB), I started to study Experimental Methods for RF Design, EMRFD. A brilliant book authored by Wes Hayward W7ZOI, Rick Campbell KK7B and Bob Larkin W7PUA. Unlike many other radio texts I had studied, I found, to my surprise, that I could easily understand the clear descriptions and concepts laid out in this book. At the same time I was given an oscilloscope, a function generator, a frequency counter and a variable voltage power supply by my friend Monk ZS4SF. I set up this equipment in my tiny shack and immediately started exploring the concepts and circuits laid out in these books. I became obsessed with measuring components and trying to understand exactly what their characteristics were. I started with simple resistor, capacitor and inductor combinations. First I would perform some simple calculations in order to be able to predict the circuit behaviour. I kept it simple initially, by experimenting with audio frequencies and components. For example, one of my earlier experiments was to calculate and then measure, the time constant of a resistor-capacitor low pass filter network. I designed an experiment using the function generator to generate the signal input to the circuit while observing the output waveform on the oscilloscope. I discovered, to my amazement, that the measured result indeed agreed with my calculated result. Through these simple experiments I gradually built up confidence in myself, my instruments and how to interpret the results. I then tried to understand what was causing the variances between the predicted results and the measured results. This thought process led me to the next level of understanding and further experimenting. All the while I was becoming better at using my calculator and at manipulating large and small numbers and the use of long forgotten engineering notations. I gained an appreciation for the decibel system and a practical feel for the logarithmic nature of the analogue world we live in. Today thinking in dB's and dBm's comes completely naturally to me.

After becoming familiar with resistors, capacitors and inductors I began to be able to identify such elements as resonant circuits and filters while studying schematics. I was now able to identify their resonant frequencies and 3dB roll-off points based purely on looking at their values. 40 meter band tuned-circuit values became familiar as did other band and audio circuit component values.

One of my favourite sources of information is the RF workbench series written by VE7BPO (now archived on his blog [http://qrp-popcorn.blogspot.ca/p/blog-page\\_9.html](http://qrp-popcorn.blogspot.ca/p/blog-page_9.html)). VE7BPO taught me the importance of the 50 Ohm RF work bench. This series led me to build a Return Loss Bridge, an RF Power Meter, an RF Signal Source and to acquire a set of fixed and switched attenuators. With these tools I was able to explore, measure and gain confidence in understanding subjects such as matching, gain, loss and distortion.

I have spent hours reading and re-reading Chapter 2 of EMRFD and then setting up simple single-transistor circuits such as the common emitter and emitter follower topologies. By varying the bias conditions, source and terminating impedances I have gained insights into the art and science of amplifier design and the inevitable trade-offs required. Each time I perform a measurement I learn something new. Upon rereading the relevant paragraphs in EMRFD I gain new insights.

I have also discovered the power of writing up my lab book and blog (ZS6RSH.blogspot.com) before, during and after the experiment. This forces a certain discipline and helps me to understand more clearly what I am striving to accomplish, what is being observed in the measurement results and what the next step should be.

In conclusion, looking back over the past three years at the wonderful road I have travelled and will continue to travel, I would suggest that the combination of studying, predicting a circuit behaviour, building the simple circuit, and measuring and comparing the result is a great path leading towards establishing a level of confidence and understanding in homebrew QRP radio design that will lead to an ability to design one's own circuits. A worthy goal indeed! This picture is where it all happens at N4HAY!



## **Snippets**

*Analysis of the diode detector* I wondered in the last Hot Iron if anybody would care to comment on the mathematical analysis by Phillip Pollock of the simple diode detector; I did get only one comment – from a member who said he was thinking about it – but I have not heard anything further! I understand that he is using an ancient slide rule to help compute his answers!

## **Thank you**

This is a convenient space to fit in a very big thank you to all the contributors to this issue of Hot Iron. Three are new authors for this journal and I very much appreciate the time put in by them (and also my regulars) to create material that I can insert straight away with very little editing. It has been particularly helpful this month as I have had to be away for long breaks in the Isle of Wight and hence out of touch. Much appreciated – thank you!

## **New Material**

If any reader can write me any sort of radio related article please do let me know. Almost any radio topic is of interest to us all so please do not hold back. Similarly, if you have any question or topic that you think needs a bit of an airing, please tell me because others are likely to share your interest. Don't worry about diagrams, I can deal with them! Tim G3PCJ