RF Oscillators

by

Jim Butler GM3ZMA

In this session we will look at a few ways of generating an RF signal;

LC Oscillator

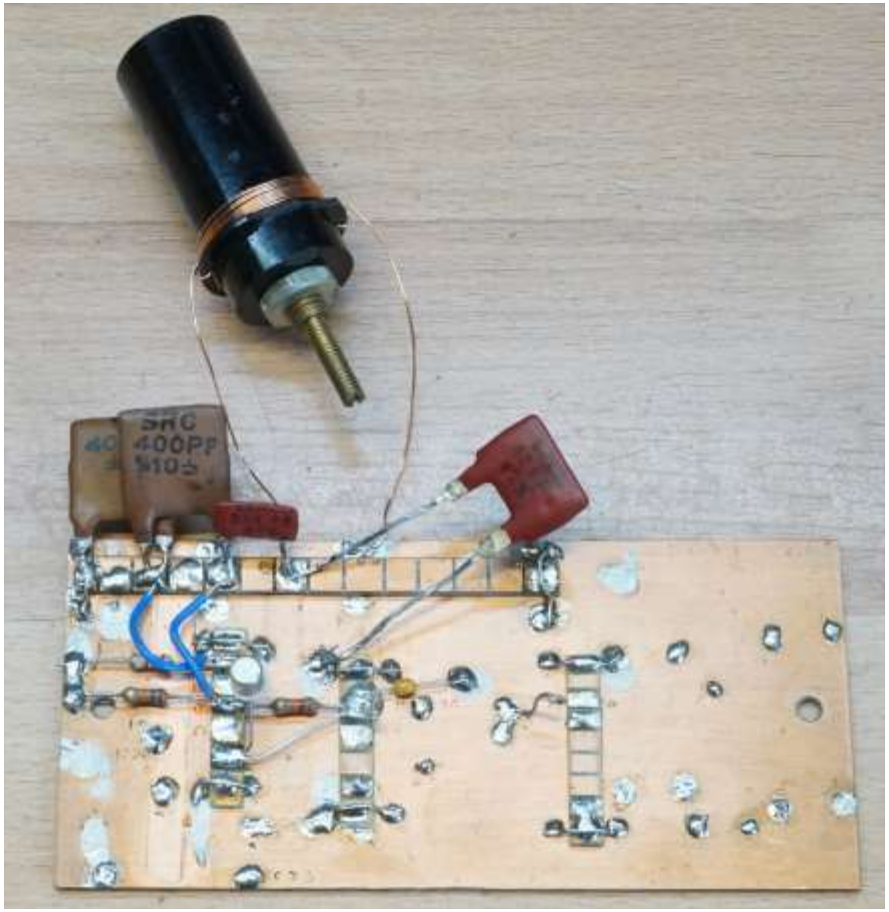
Crystal oscillator

Crystal Oscillator Module

Simple Phase Locked Loop (PLL) synthesizer

Wide range (0 to 400MHz) Direct Digital Synthesizer (DDS)

A basic Colpitts oscillator



A basic Colpitts circuit built on a scrap of circuit board material.

This is simply a prototype to determine if the circuit will oscillate (it does).

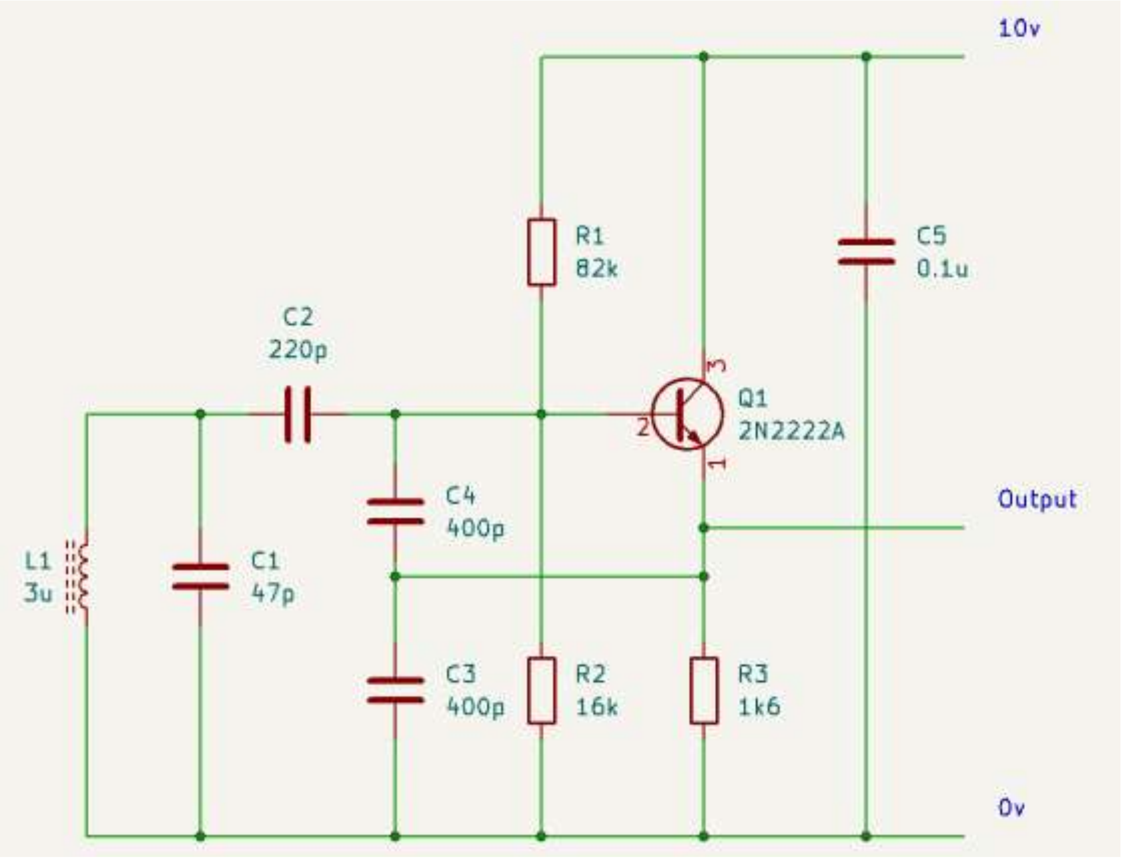
The components of the tuned circuit were calculated as per the book: Solid State Design for the Radio Amateur, Page 32, fig 2.

Closest preferred values were used in the prototype.

The frequency is 7MHz.

This is a bad example of "How to build an RF Oscillator", it has very poor mechanical stability, the frequency changes when nearby objects are moved.

The Schematic



L1, C1, C2, C3 and C4 are all frequency determining components.

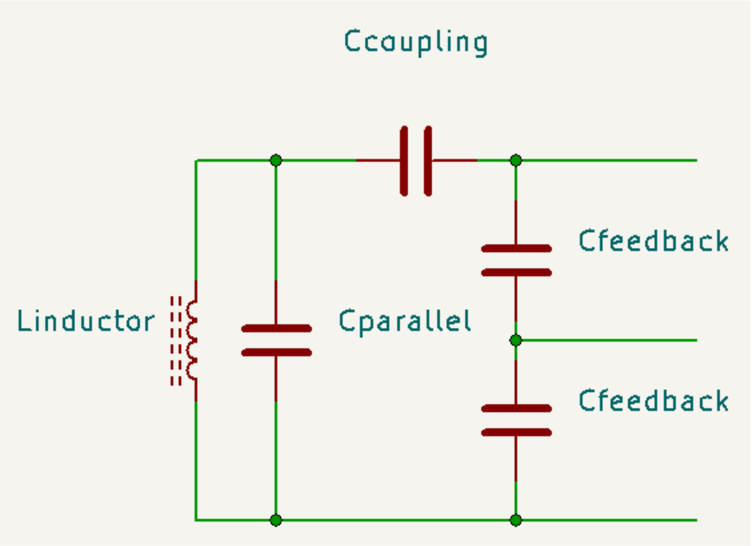
Calculating the component values

The components of the tuned circuit were calculated as per the book:
Solid State Design for the Radio Amateur, Page 32, fig 2.

That text suggests that the **Reactance** of the various capacitors and the inductor should be as follows:

Xcfeedback	=	45 Ohm
XCcoupling	=	100 Ohm
Xinductor	=	140 Ohm

C parallel is selected to give the desired frequency.

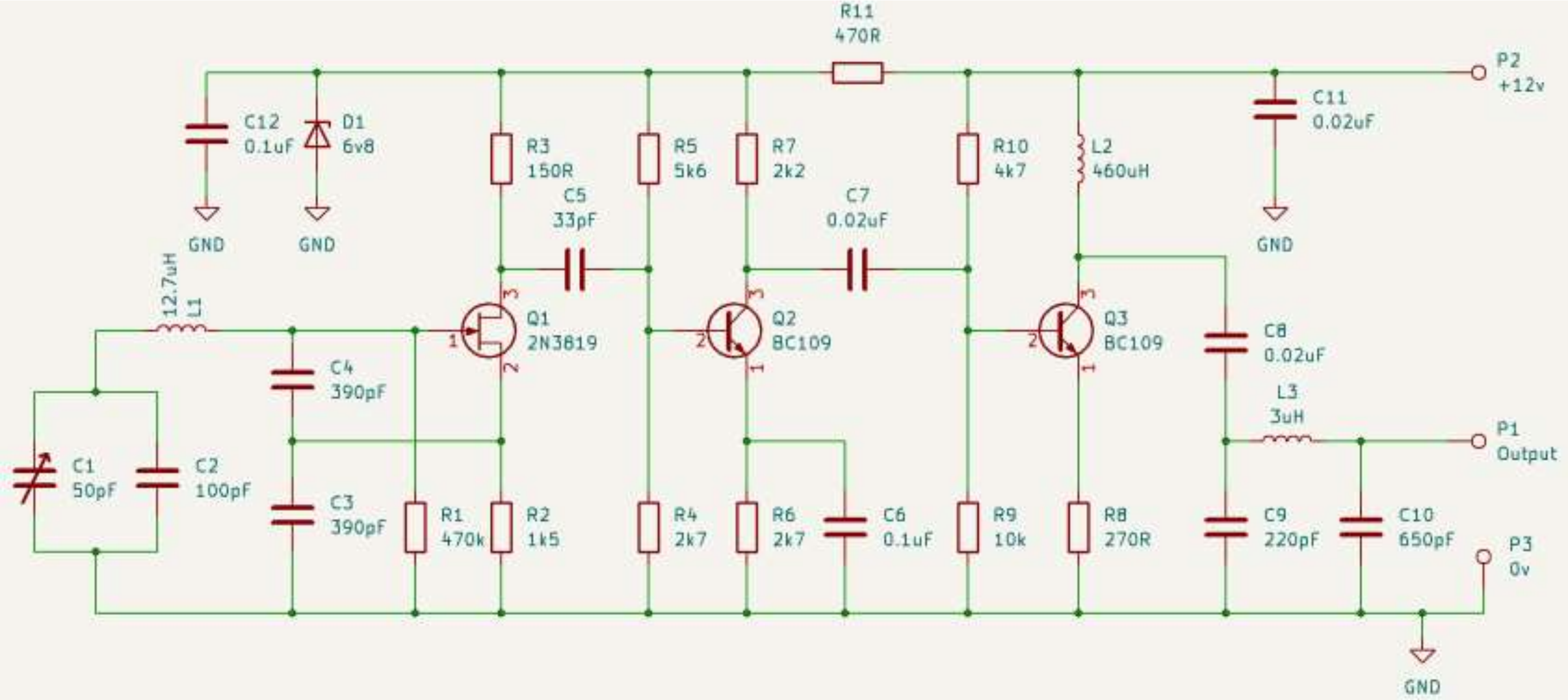


To operate at 7MHz:

Initial calculations suggested			**Actual values used**
Cfeedback	=	505pF	400pF
Ccoupling	=	227pF	220pF
Cparallel	=	43pF	47pF
Linductor	=	3.18uH	3.2uH (Core partly inserted)

A better Colpitts* oscillator

* Actually it is a Clapp Oscillator, (a close relation to the Colpitts) the inductor is in series with the tuning capacitor.



This oscillator tunes from 5.0 to 5.5MHz and was built for use in a 80 and 20 metre receiver with a 9MHz intermediate frequency.

Notable mechanical details

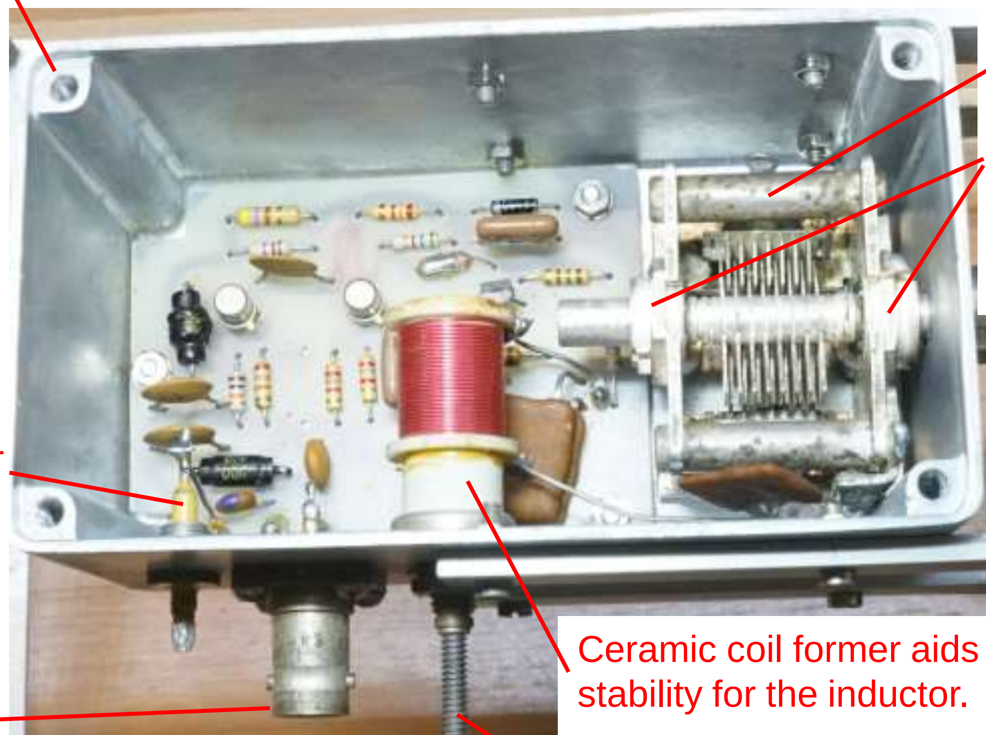
Diecast box for mechanical rigidity and RF screening.

Tuning capacitor.

Heavy stiff frame,

spindle supported by ball bearings at both ends,

are aids to mechanical stability



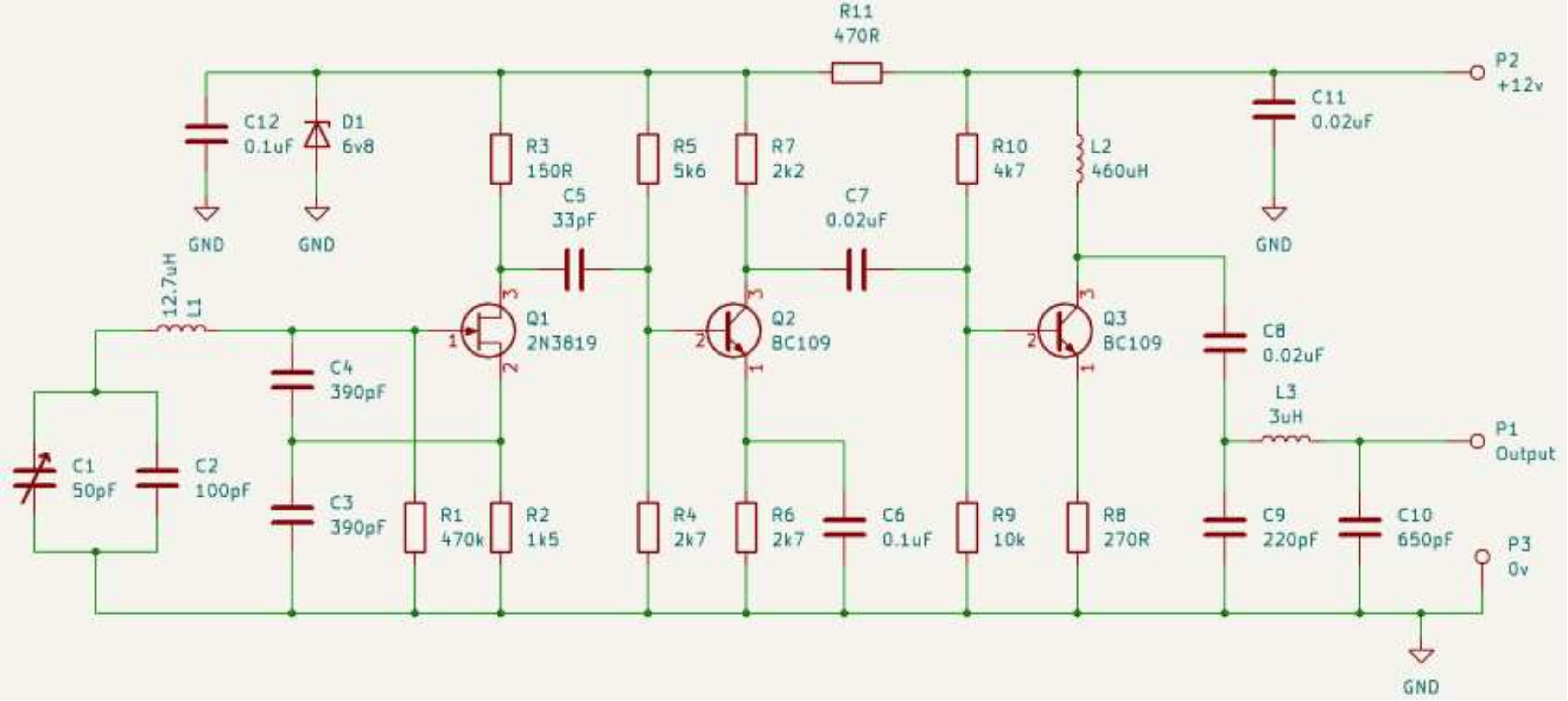
Feedthrough capacitor for the DC supply.

BNC connector for RF output connection, provides screening.

Ceramic coil former aids stability for the inductor.

Adjustment screw, external to the box aids final frequency adjustment.

Notable circuit details

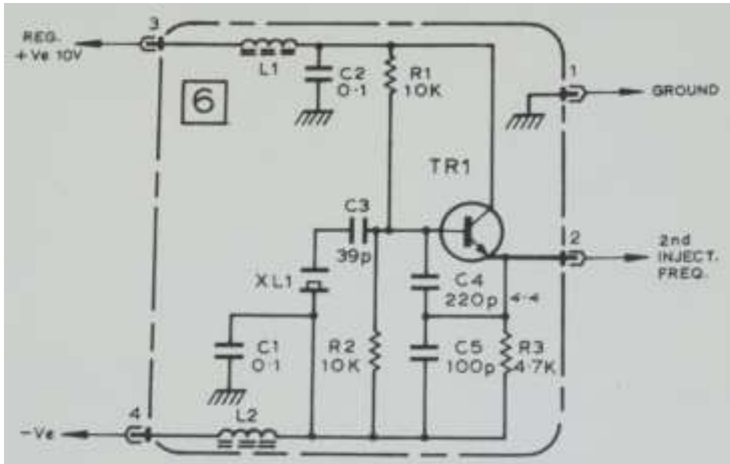


Zener diode D1 provides a stabilized supply for the oscillator Q1 and the first buffer amplifier Q2.

Two buffer amplifier stages Q2 and Q3, isolate the oscillator Q1 from load variations on the output.

The lowpass filter C9, L3, C10 gives a modest attenuation of harmonics.

Crystal Oscillator using discrete components



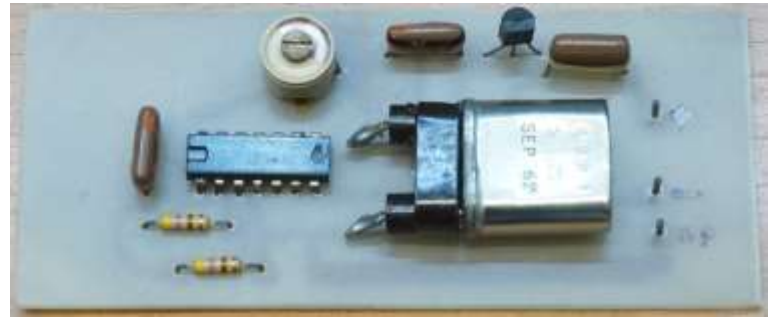
The second conversion oscillator from a PYE Westminster.

The circuit is a variation of the Colpitts.
TR1 is configured as an emitter follower, C4 and C5 form the feedback, and the frequency is determined by crystal XL1 in series with C3.
The crystal frequency is 11.155MHz

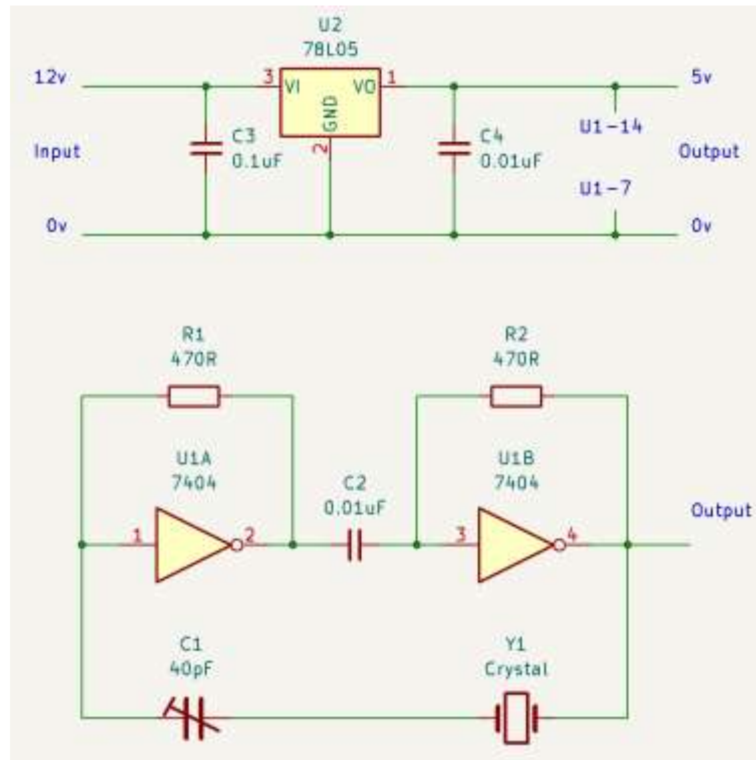
The components L1, L2, C1 and C2 are there because the Westminster circuits were floating from the chassis to accommodate installation in vehicles with positive or negative earth electrical systems.

And another one…

Found in my “projects archive”.
I don’t know when or why I built it, but it does work.



Plug in a 2.000 MHz crystal and this happens:



But beware, not all crystals work in all oscillator circuits.
Some give strange results, or do not work at all.

Crystal Oscillator Modules

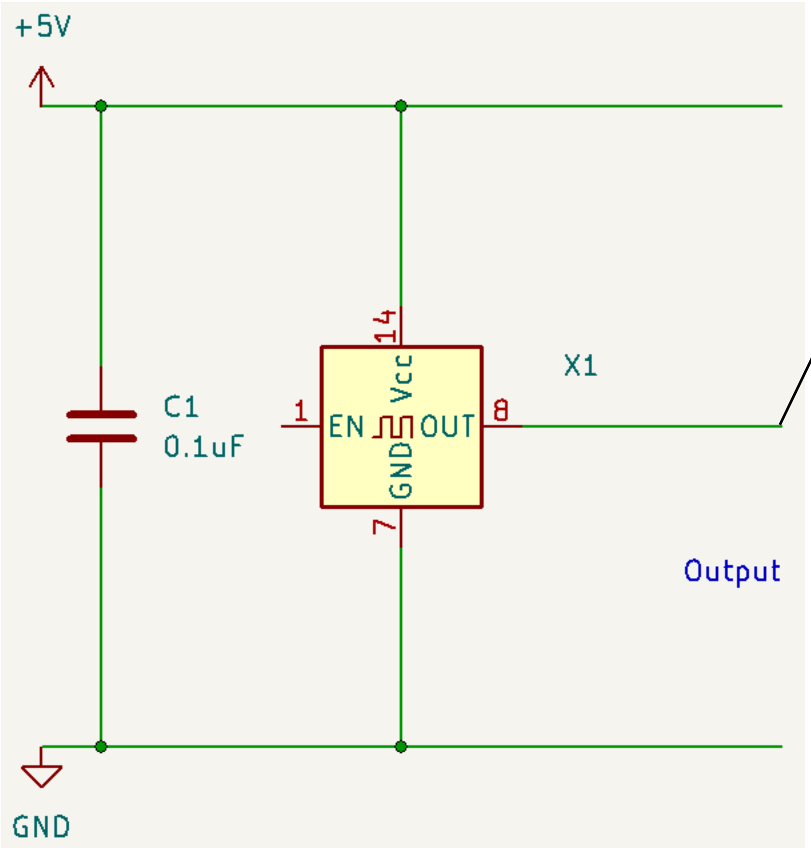
Crystal oscillator modules have traditionally been available in metal cans, conforming to a DIP14 or DIP8 profile.

Usually only the four corner pins are installed, pins 1, 7, 8, 16. Where the module does not have an Enable pin, pin 1 may not be fitted.

Three oscillator modules, two DIP14 profile and one DIP8 profile.
The 10.000 MHz module has a trimmer capacitor for adjustment to exact 10.000000 MHz.

Crystal Oscillator Module – Making it work.

Connect the oscillator module to a 5v supply, some modules have an ENable pin to turn the output On/Off. Many newer modules have a lower supply voltage rating, 3.3 or 2.8v for compatibility with newer logic types.



Most oscillator modules have a square wave output, the amplitude is determined by the supply voltage.
i.e. a module designed for a 5v supply will have 0 to 5v output,
and a 3.3v module will have a 0 to 3.3v output.

Crystal Oscillator Modules – How accurate?

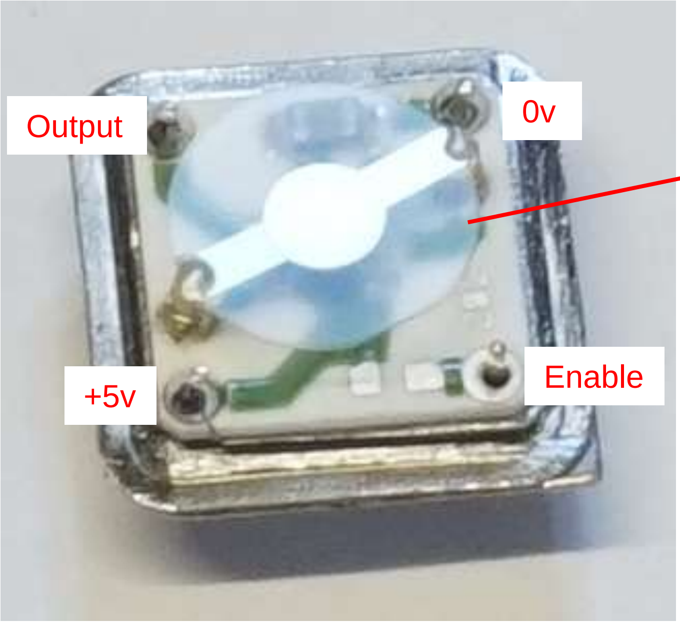
Testing a few modules selected at random from my “parts archive” gave the following results:

Marked Frequency (MHz)	Measured Frequency (MHz)	Error (Hz)	
10.000	9.9999997	-0.3	Note 1
23.961600	23.961501	-399	
30.000	29.999810	-199	
40.000	40.001900	+1900	Note 2
50.000	49.999530	-470	
60.0000	60.000600	+600	

Note 1 This module has a trimmer capacitor to adjust the frequency, and was adjusted to be very close to 10.000000 MHz at some time in the last two years.

Note 2 This is the oscillator module fitted to the AD9910 DDS Evaluation Board.

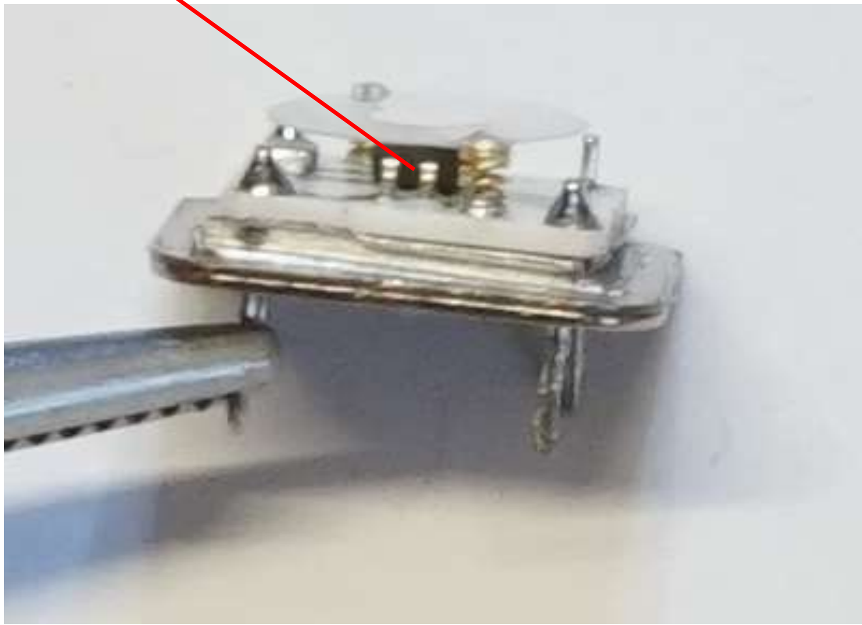
What's in the box?



Note that pin 1 (Enable) is not connected, this module did not have this control available.

Cutting the top off a faulty module, we can see the disc of quartz which makes the resonant element.

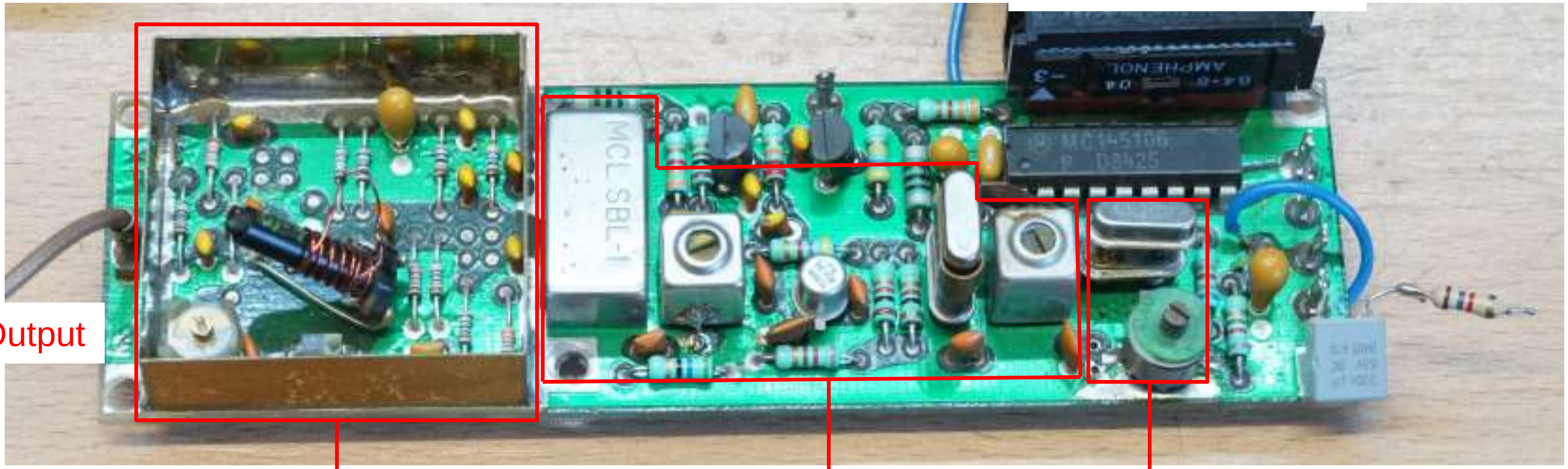
Looking under the quartz, we can see a 6 pin integrated circuit which makes the oscillator circuit.



A Basic Synthesiser

A simple synthesizer module from a Marine Band radio, based on a Motorola MC145106 integrated circuit (1970s technology ?). This unit has been modified during various experiments to give an RF output in the 51 MHz region.

Digital Inputs from the controller
set the programmable divider in the MC145106



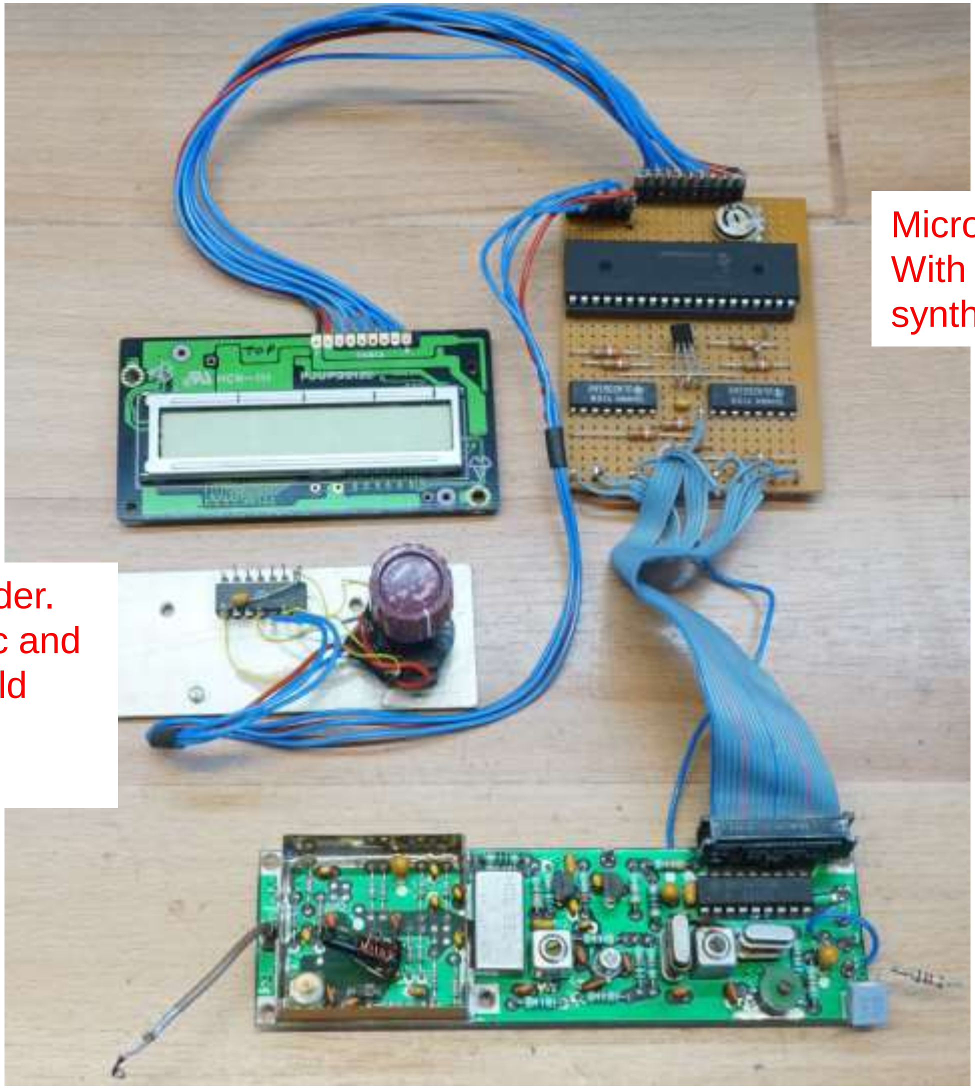
RF Output

Voltage Controlled Oscillator (VCO)
Note the makeshift coil used to change the frequency from ~168 MHz to 51 MHz.

Crystal Oscillator and Mixer
Converts the 50MHz VCO frequency down to less than the 4MHz maximum frequency of the MC145106

Crystal 10.24MHz
Sets the 10kHz reference frequency for the MC145106

Basic Synthesiser test setup



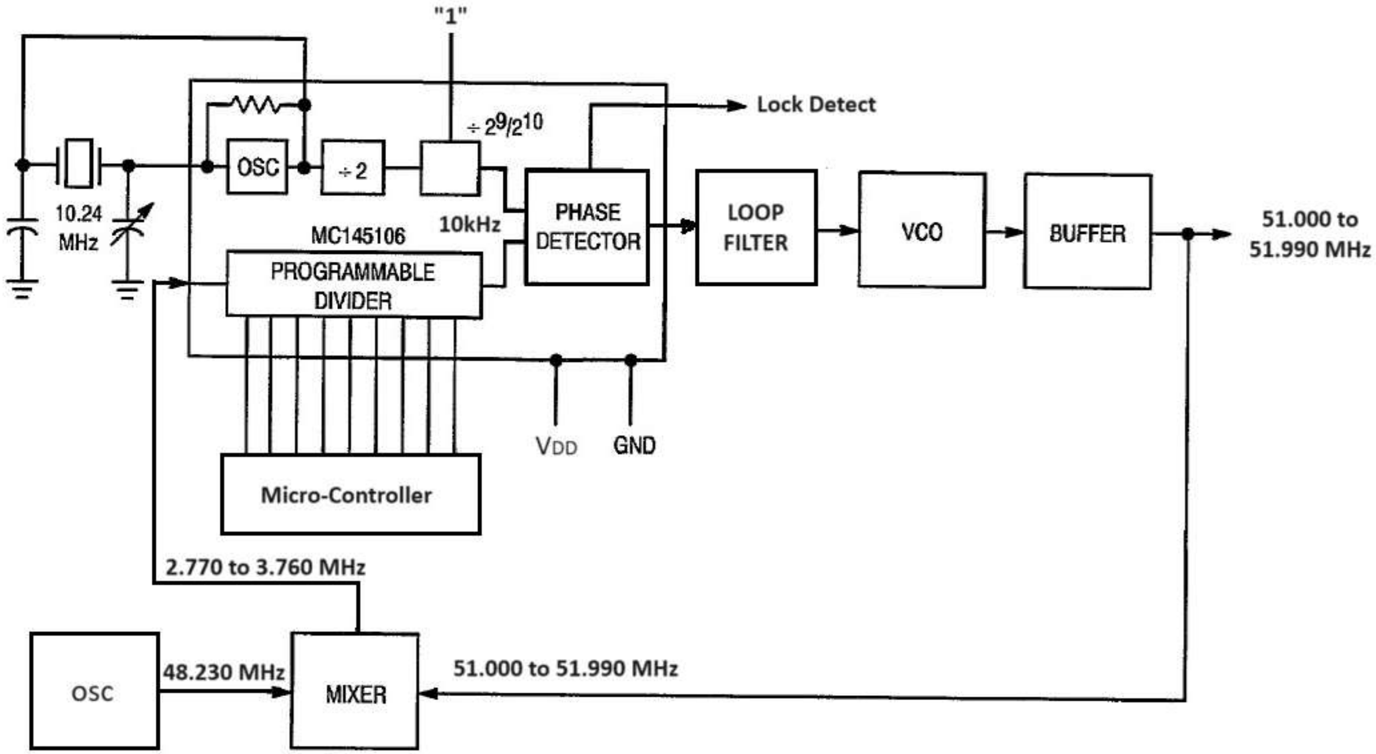
LCD Module
Displays the required frequency

Home made quad encoder.
Uses the interrupter disc and opto switches from an old "ball mouse"

Microcontroller
With interfaces to the CMOS synthesizer IC

Synthesiser Module

Block Diagram of the Basic Synthesiser



Setting the frequency

The microcontroller writes a binary number to the programmable divider in the MC145106.

If we want a frequency of 51.50 MHz, that number N must be

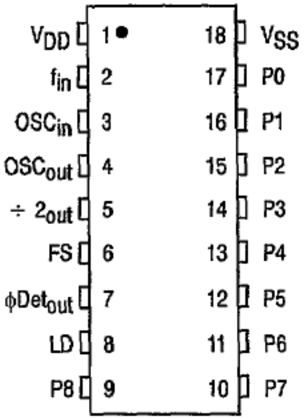
$$N = Foutput - 48.23$$
$$N = 51.5 - 48.23$$
$$N = 327(decimal)$$

Converting to binary, we get N = 101000111
This is connected to inputs P0 to P8 of the MC145106 as

(P8 is MSB)

P8	P7	P6	P5	P4	P3	P2	P1	P0
1	0	1	0	0	0	1	1	1

MC145106
Pin Assignments

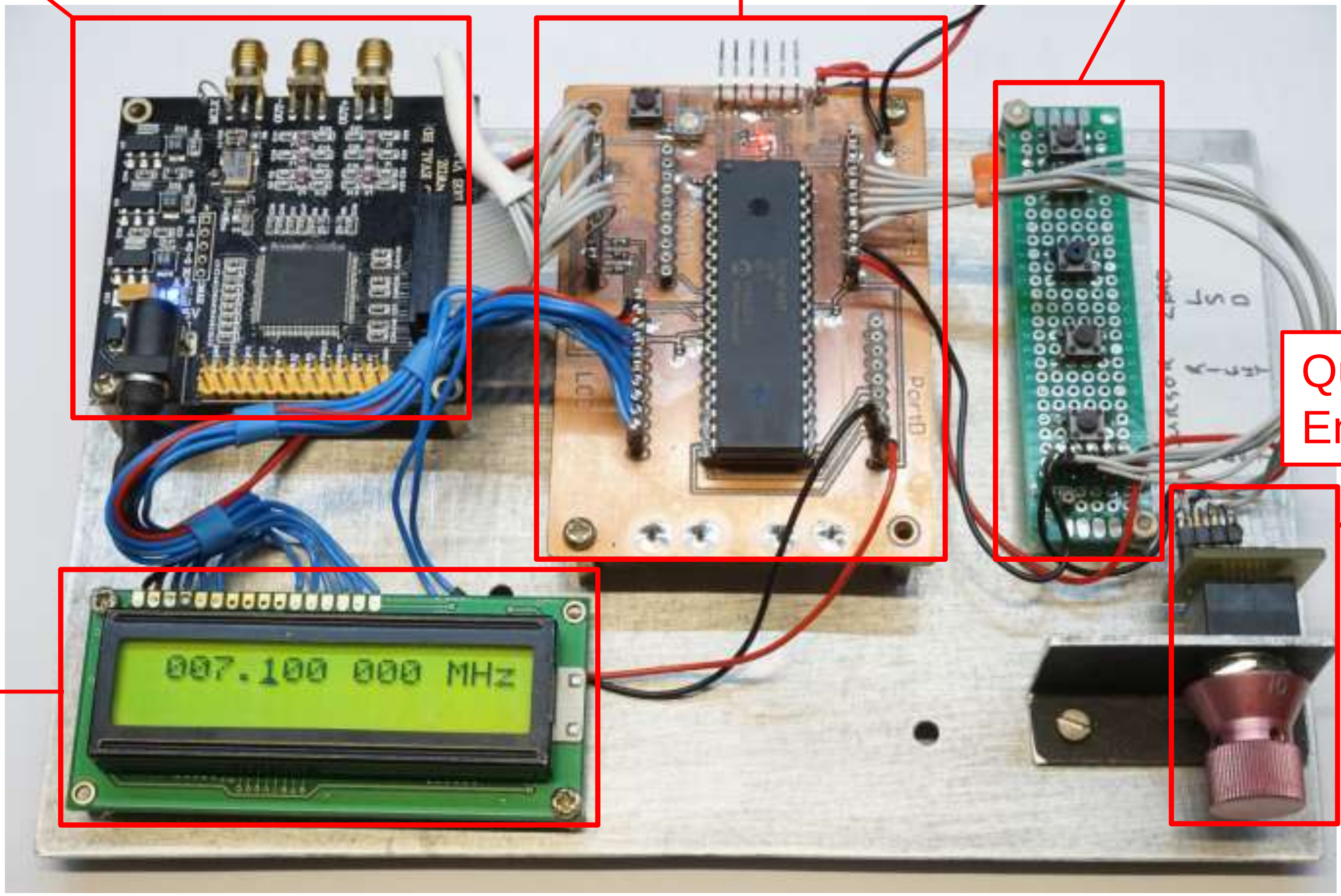


Direct Digital Synthesiser – Development Board

AD9910 DDS Evaluation Module

PIC 16F887 Micro-Controller Module

Pushbutton Switches

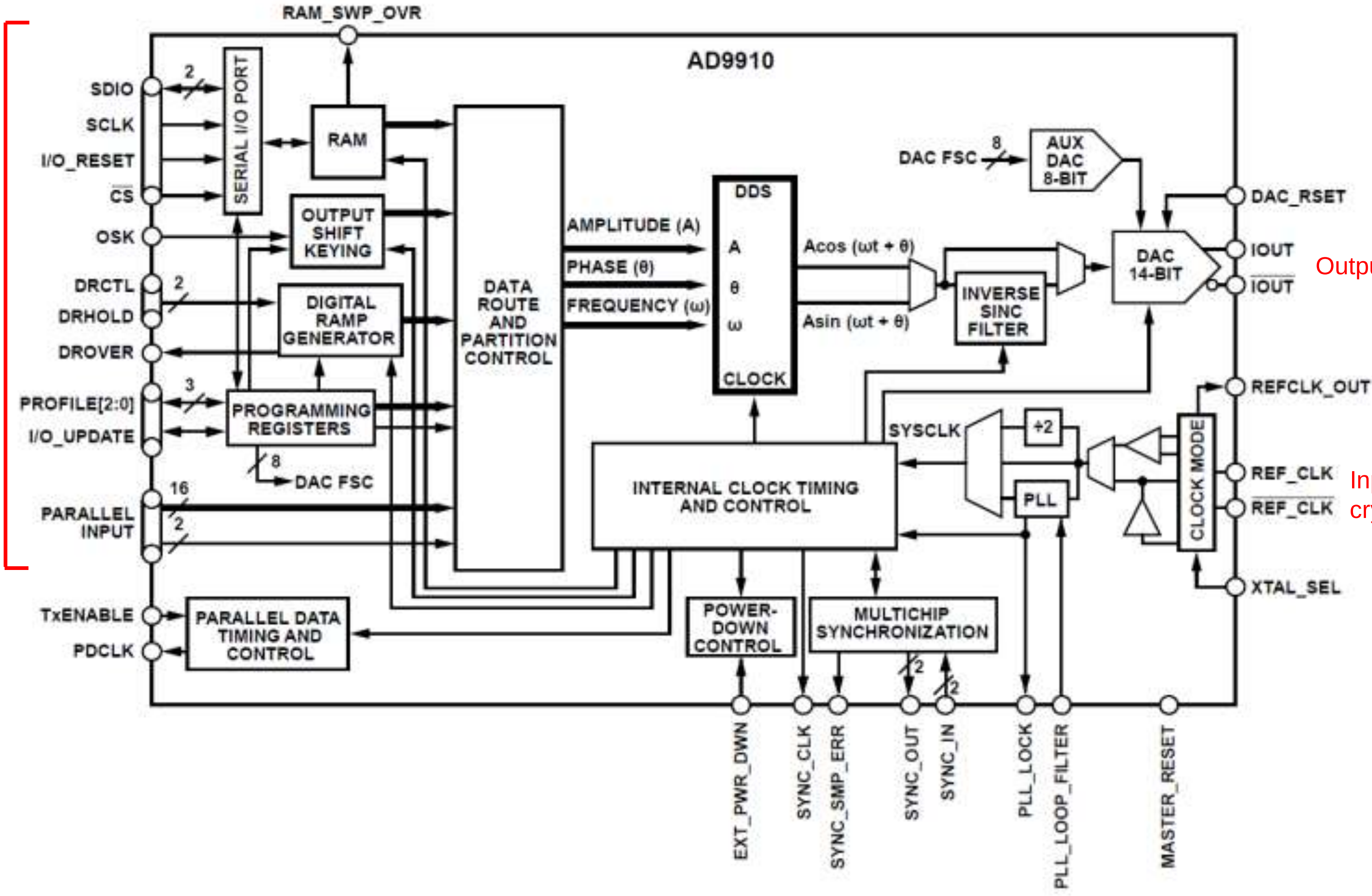


Quadrature Encoder

LCD Display Module

AD9910 Block Diagram

Control Inputs from micro processor



Output signal

Input from crystal oscillator

From AD9910 DataSheet

Setting the frequency

The microcontroller writes a 32 bit **F**requency **T**uning **W**ord to the AD9910
The FTW is determined by the calculation

$$Fout = \frac{FTW}{2^{32}} \times Fsysclock$$

Where $Fout$ is the required output frequency,
and $Fsysclock$ is the DDS system clock frequency, determined by the reference crystal frequency and the clock multiplication factor (if enabled). In the development board used here, the 40MHz crystal frequency is multiplied by 25 to give an $Fsysclock$ of 1Ghz.

Re-ordering the above equation to find the FTW:

$$FTW = \frac{Fout \times 2^{32}}{Fsysclock}$$

To set the output frequency to 1Hz, the FTW will be 00000004 (in hexadecimal, to the nearest integer)

The microcontroller writes to the AD9910

Select Profile Register

Amplitude Scale Factor (16 bits)

Phase Offset Word (16 bits)

Frequency Tuning Word (32 bits)

Three digital outputs from the microcontroller:

3 - Update I/O

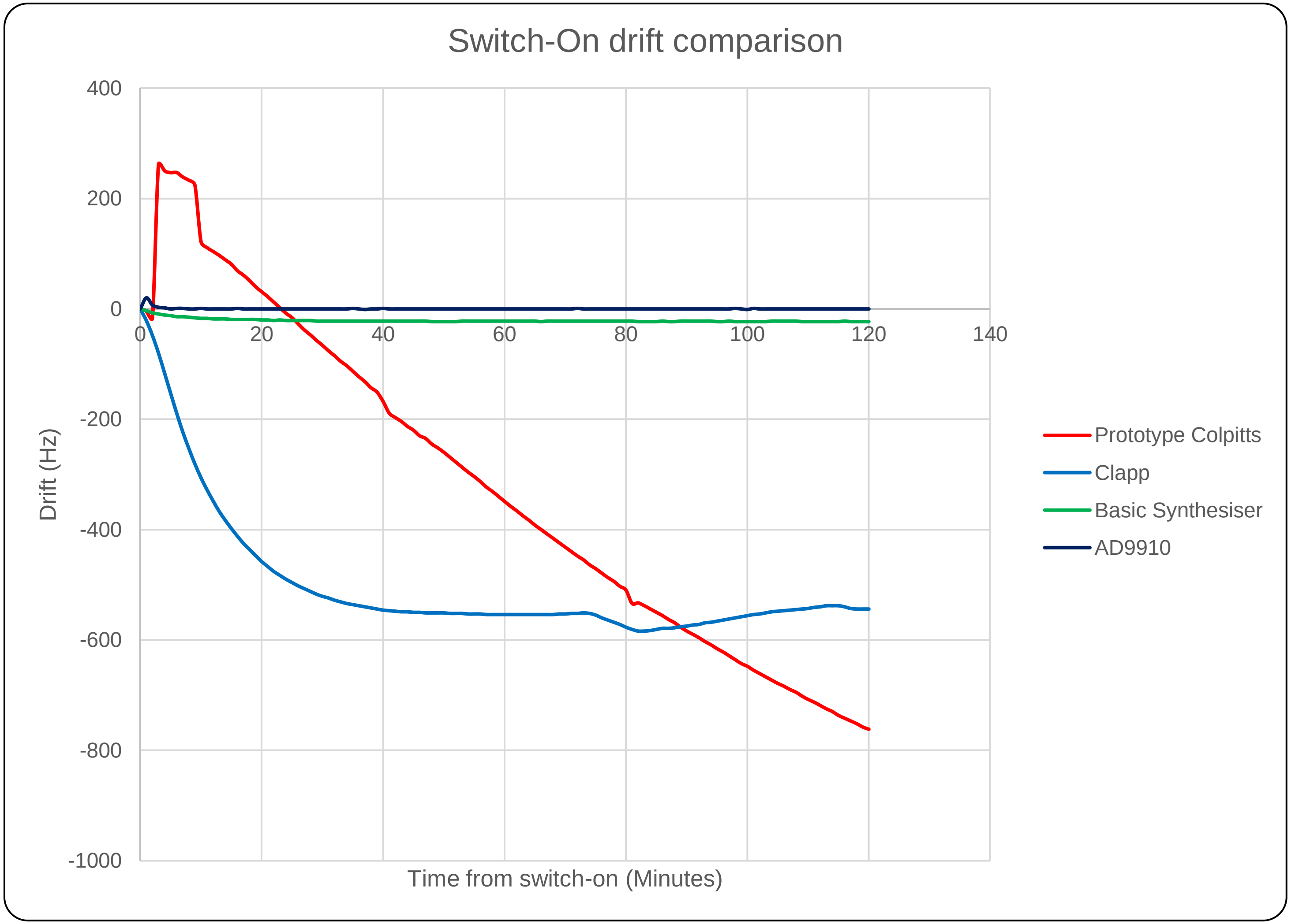
Transfers the tuning information from the buffer registers to the active registers to set the DDS output.

1 - Clock

The Clock and Data signals write the tuning information to the I/O buffer registers in the AD9910

2 - Data

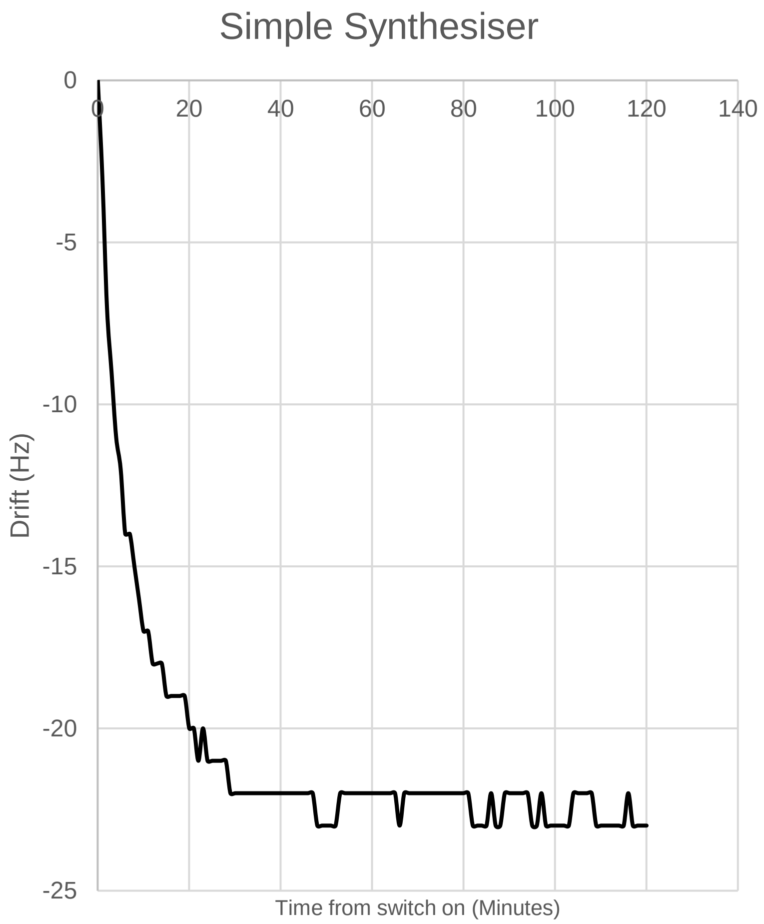
Frequency Drift Comparison

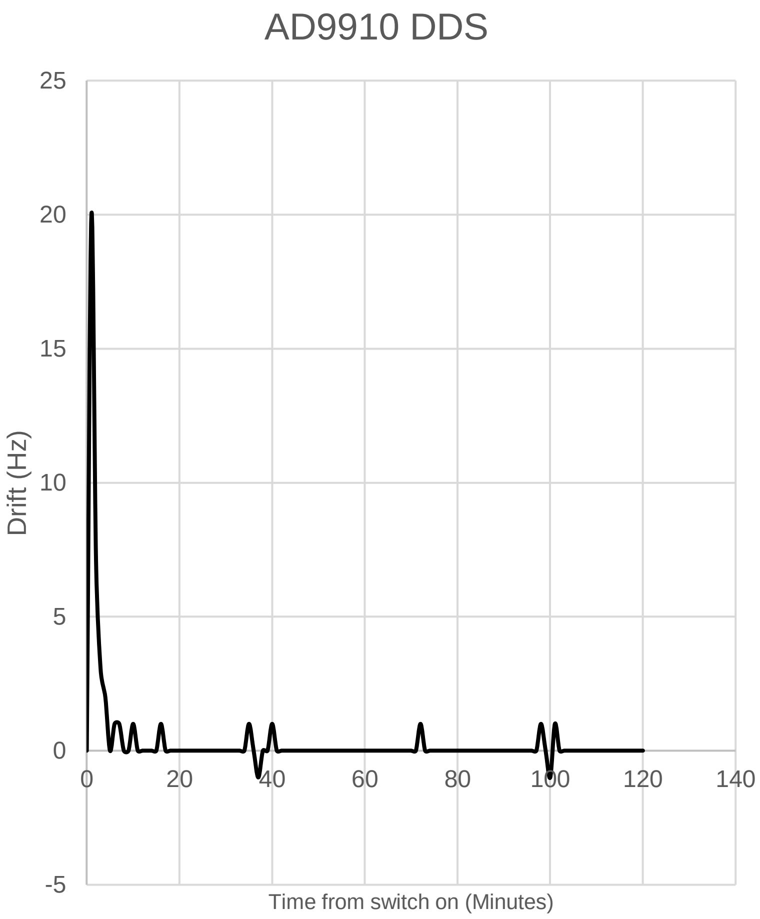


Each oscillator in turn was switched on from cold and the frequency measured automatically every minute for 2 hours.

The resulting warm-up frequency drift is graphically displayed here.

Expanded drift plots for the two synthesisers





The End