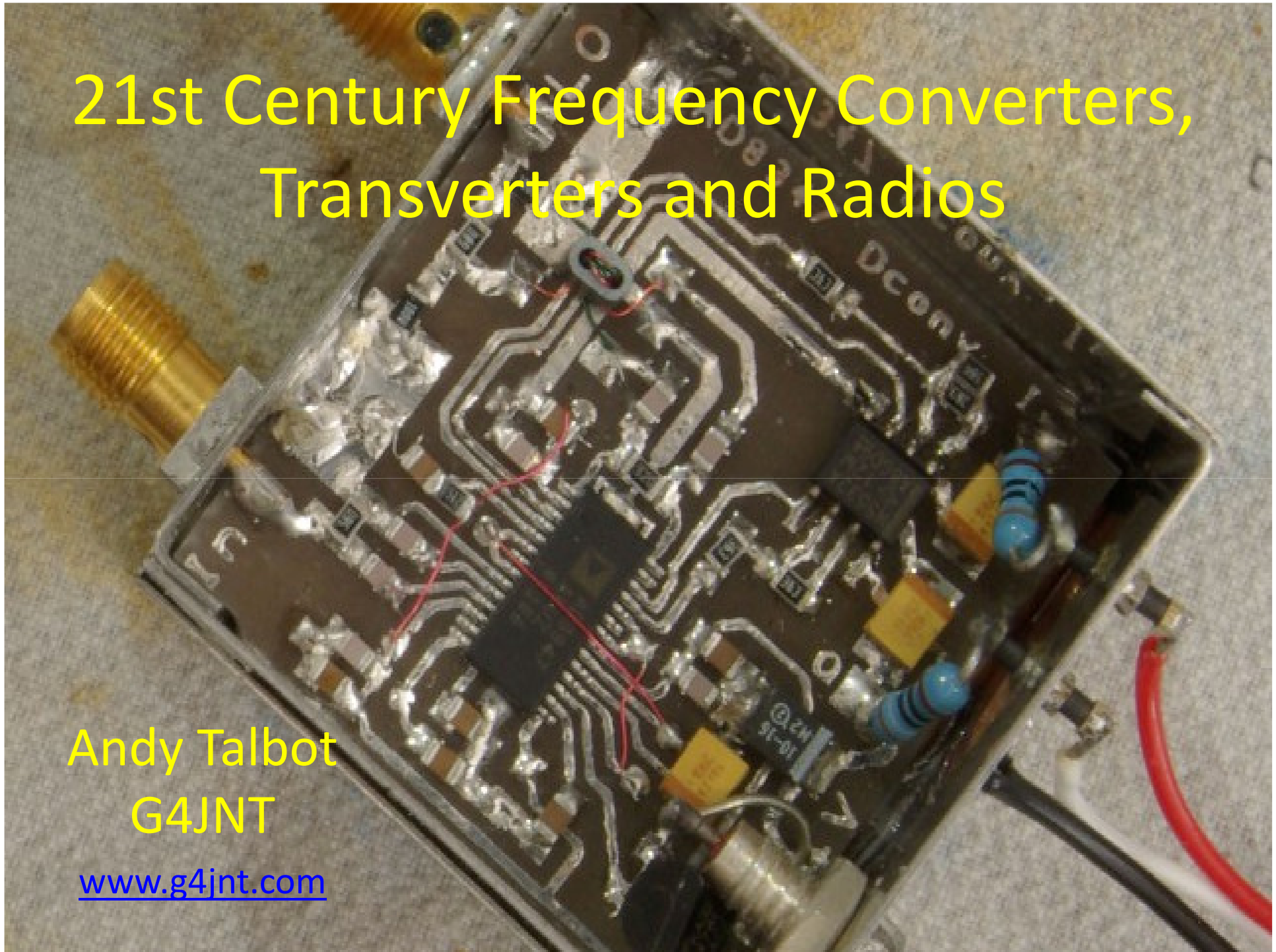


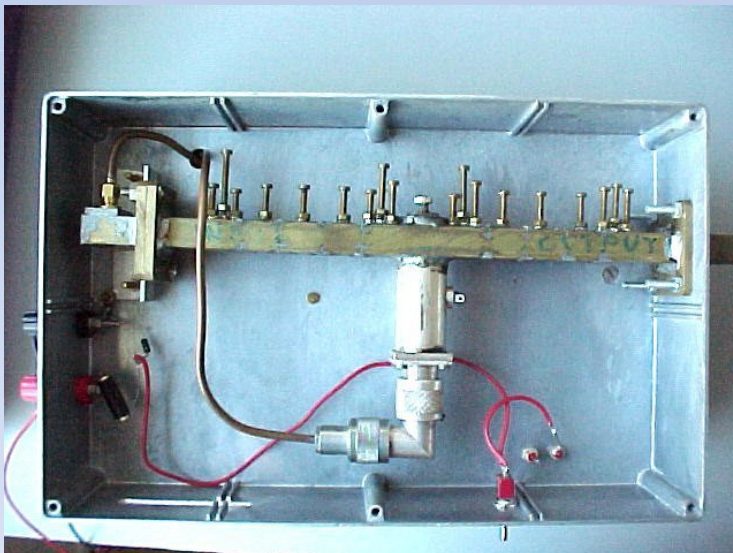
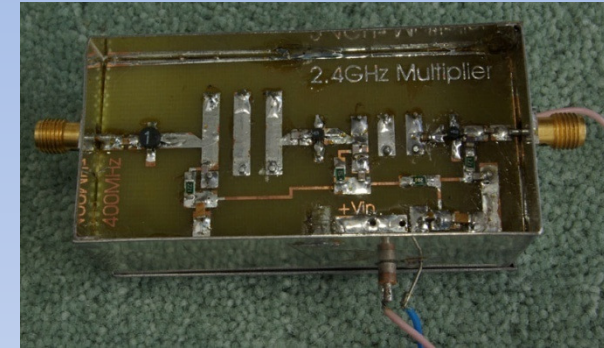
21st Century Frequency Converters, Transverters and Radios

Andy Talbot
G4JNT

www.g4jnt.com



What we used to build



Replace with minimum
tuning, wideband
integrated solutions

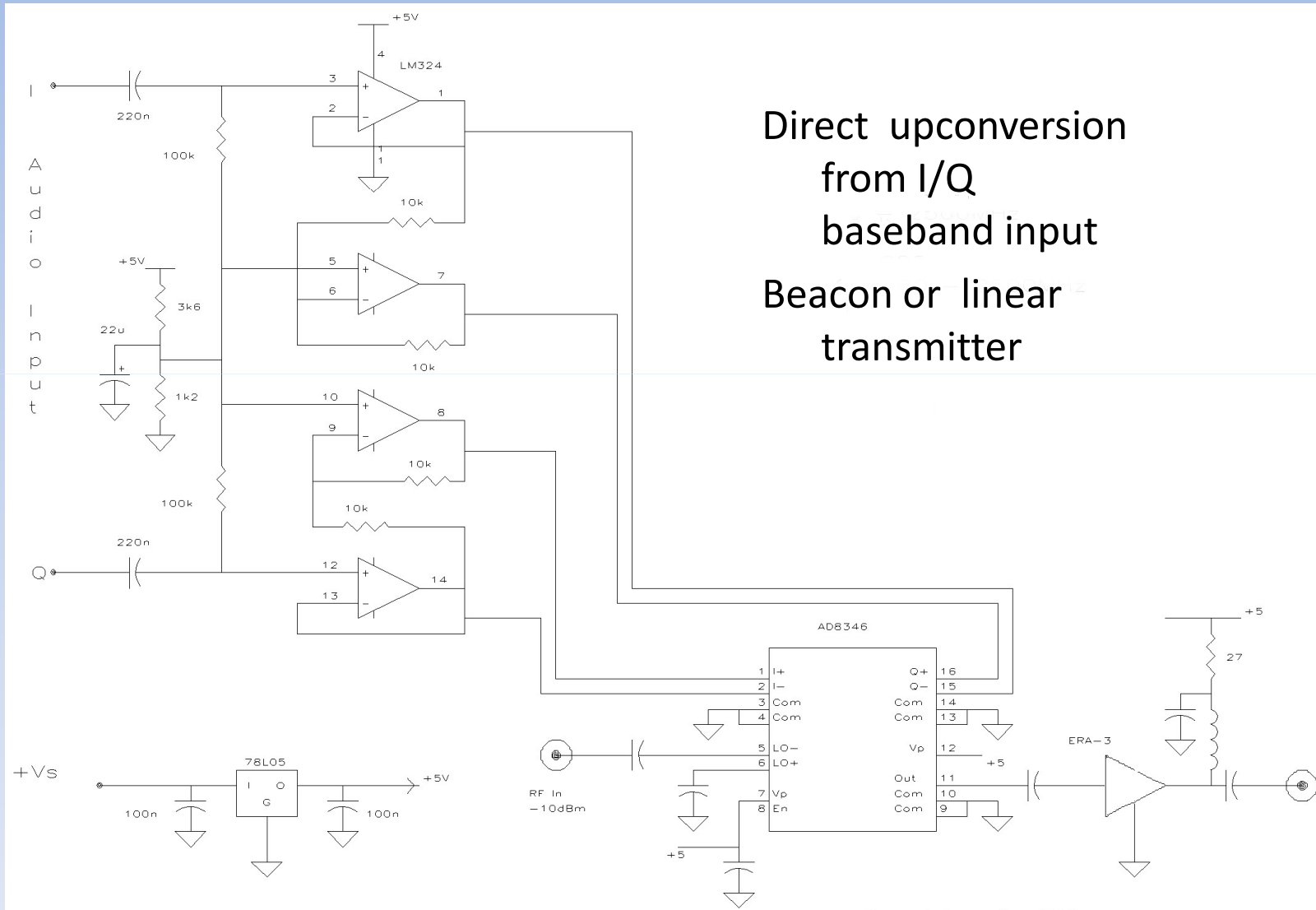
Background

- The mobile phone and modern RF industry give us nice RF chips - for peanuts
- Frequency Converters and Synthesizers
 - AD8347 £15
 - 0.8 – 2.6GHz Downconverter,
 - 60dB gain and AGC.
 - AD8346 Upconverter £12
 - LMX2326 Fixed synth – 2.6GHz £2.93 (RS)
 - LMX2470 2.5GHz FractN synth, £6

Frequency Conversion

- Single Chip Up and Down convert.
- 800 – 2600MHz – but will usually work higher
 - Other chips cover HF to UHF
- IF DC – 50MHz
 - Baseband or IF
- Low RF input power -15dBm
 - Linearity similar to diode mixers
- Downconverter - 60dB DC gain control

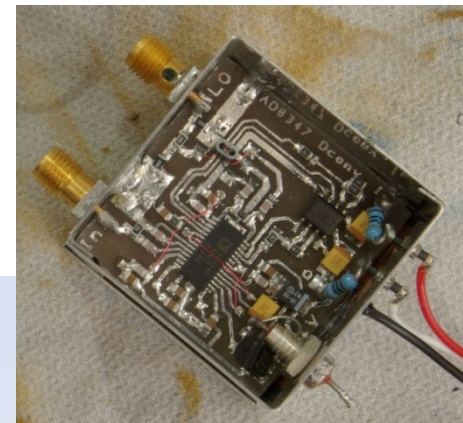
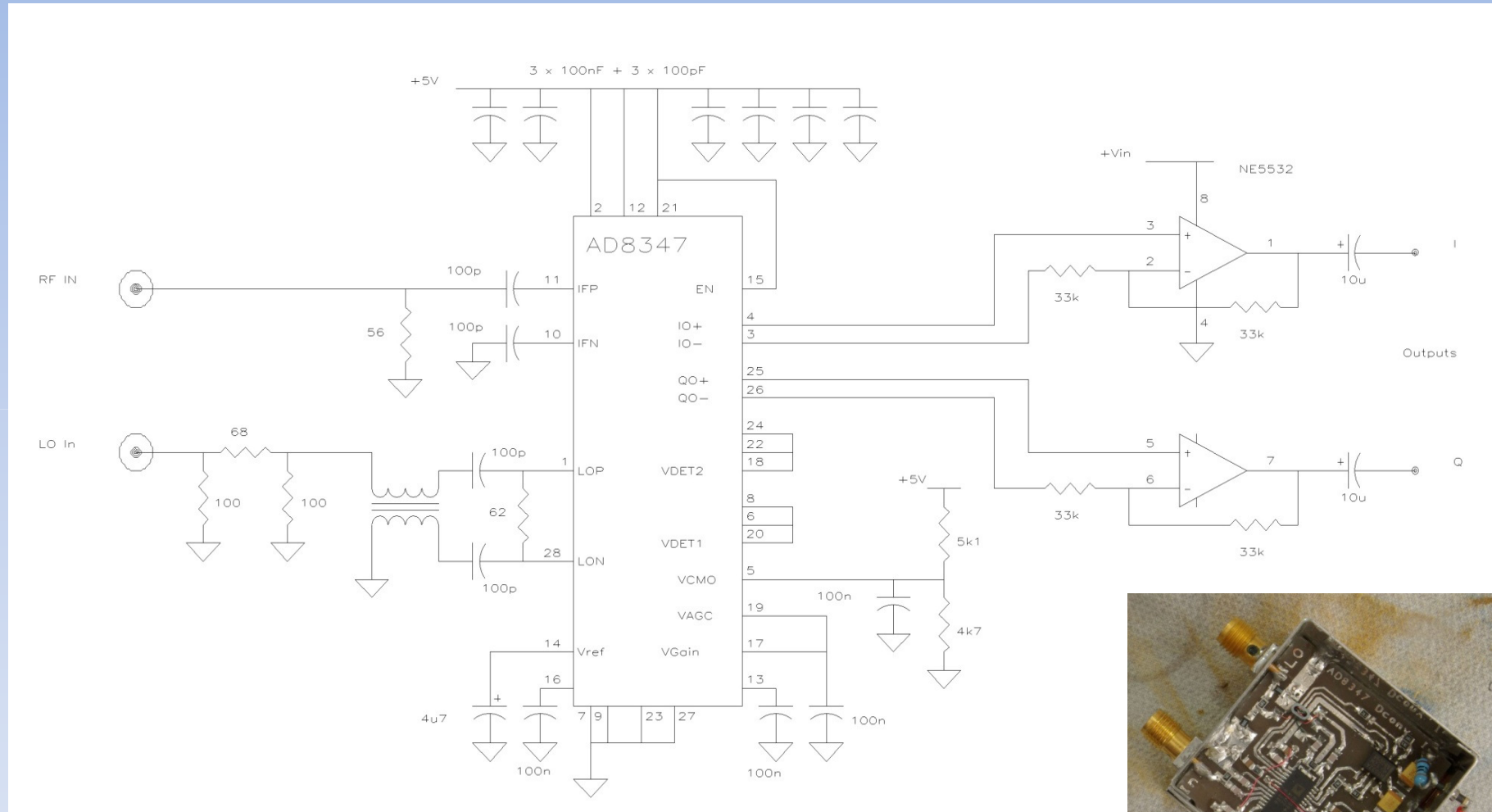
1.3 and 2.3GHz Tx Source



Baseband processing

- Replacement for the Transceiver
- SDR Software, Soundcard input / output
 - Limited Tuning over few tens of kHz
 - WinRad, Rocky, SDRadio.....
 - Filters galore
- Standalone hardware
 - Kit/Module with DSP chip, audio amp – SDR2GO
- Polyphase / Audio 90 degree networks

Direct Conversion Receiver 1.3GHz, 2.3GHz, (3400MHz)



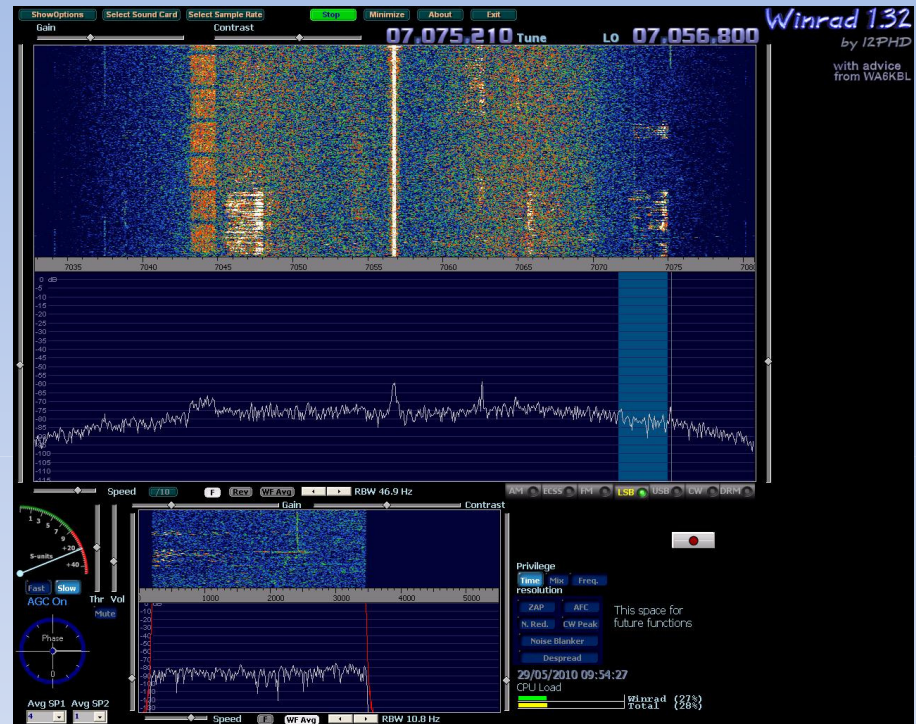
Direct Conversion Software

Plenty of Receiver software.

Typically allows tuning $\pm 24\text{kHz}$

Not much for Tx.

G3PLX basic prog mic input, IQ out, $\pm 800\text{Hz}$ tuning. + AM/FM



USB / Bluetooth
Headset Mic
Input



Rx & Tx standalone (no PC)

SDR2GO – Baseband
I/Q Mod/Demod
(Si570 control not
used)

SSB with mic or line
input

On-Off carrier (with
audio sidetone)



The Downside

- Direct Conversion suffers from input rectification.
 - GSM, 3G, DECT , WLAN
 - MASSIVE pulsed signals in local environment
- Input filtering
- Ok for use out in field,
 - Beacon monitor works OK –

OR the Conventional Route

IQ Conversion to RF & 28MHz Transceiver

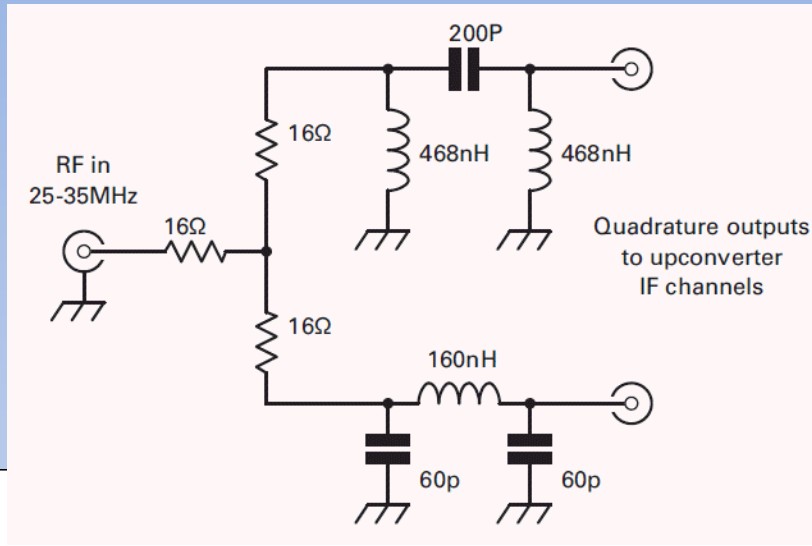
The AD8346 and '47 work with IFs to >50MHz

IQ network for conventional transverter design
no need for serious image filtering.

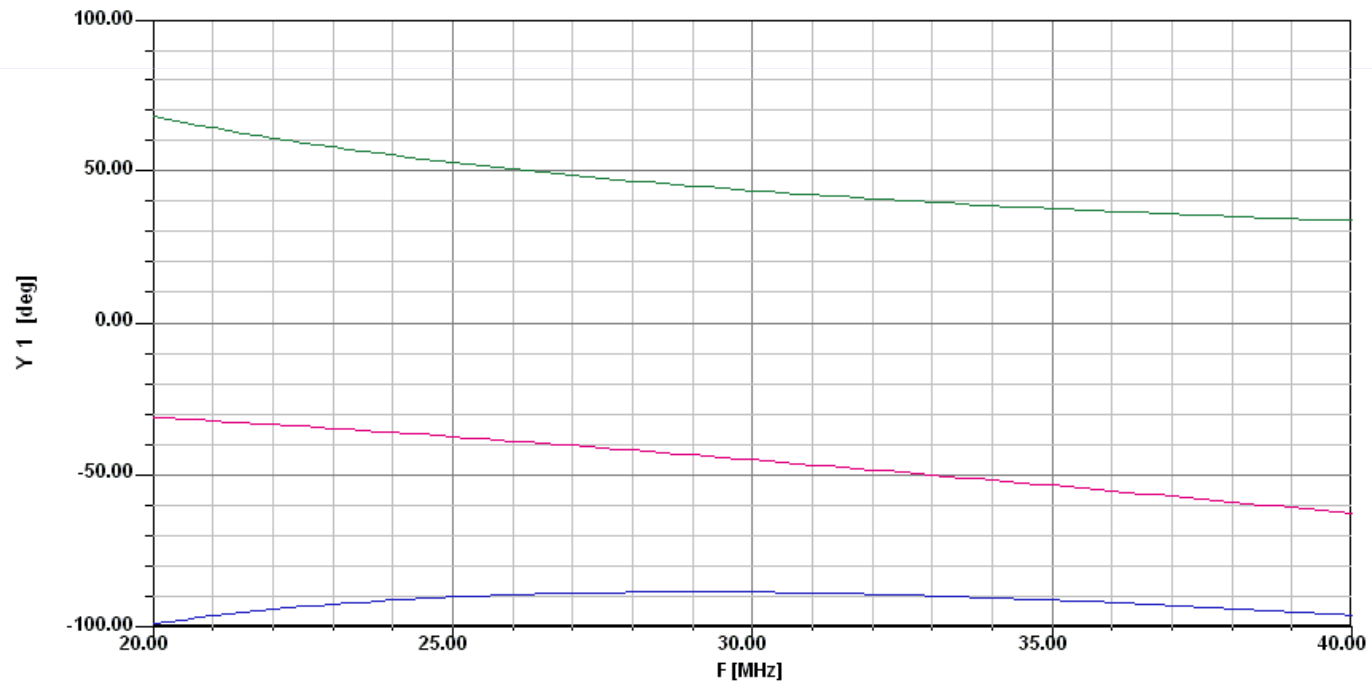
Off-the-shelf Minicircuits PSCQ-2-40 quad hybrid 23 – 40MHz
35dB sideband rejection

LOW IF – 100kHz to MHz. RC tuned 2nd LO

Hi/Low Pass 90° phase shifter



06 Dec 2011



Y1	
ang(S21) HPLPPh1	
Y1	
ang(S31) HPLPPh1	
Y1	
ang(s31)-ang(s21) HPLPPh1	

Local Oscillators

Fixed Frequency
Synthesizer

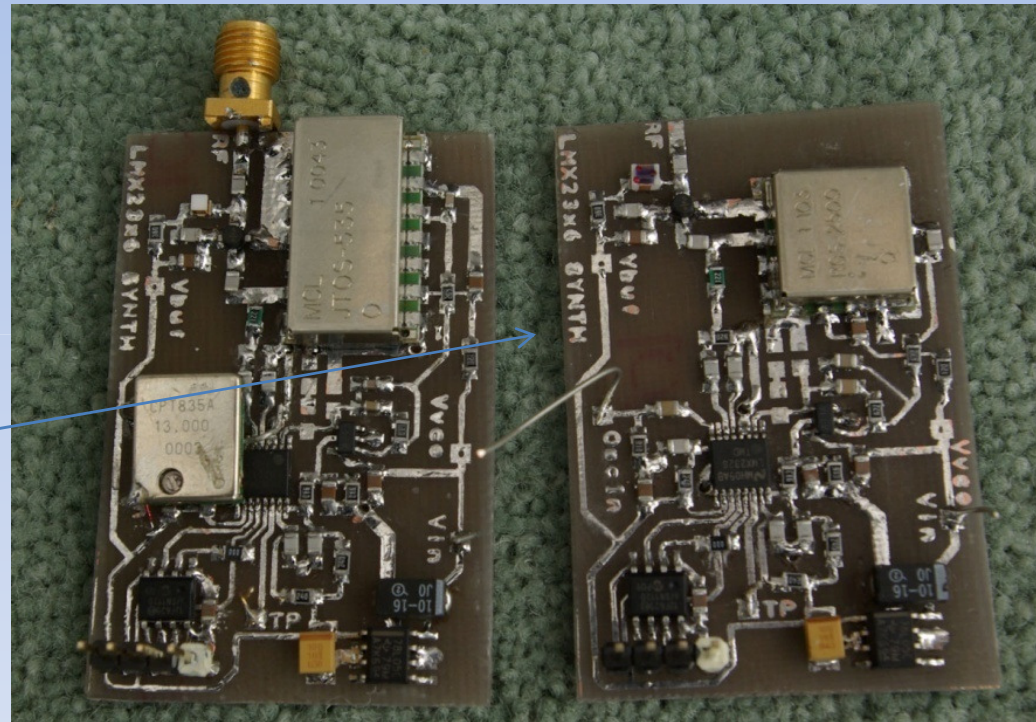
Ideal for

Transverter LOs

LMX2326 to 2.6GHz

OR

AD41020 to 18GHz



Integer N

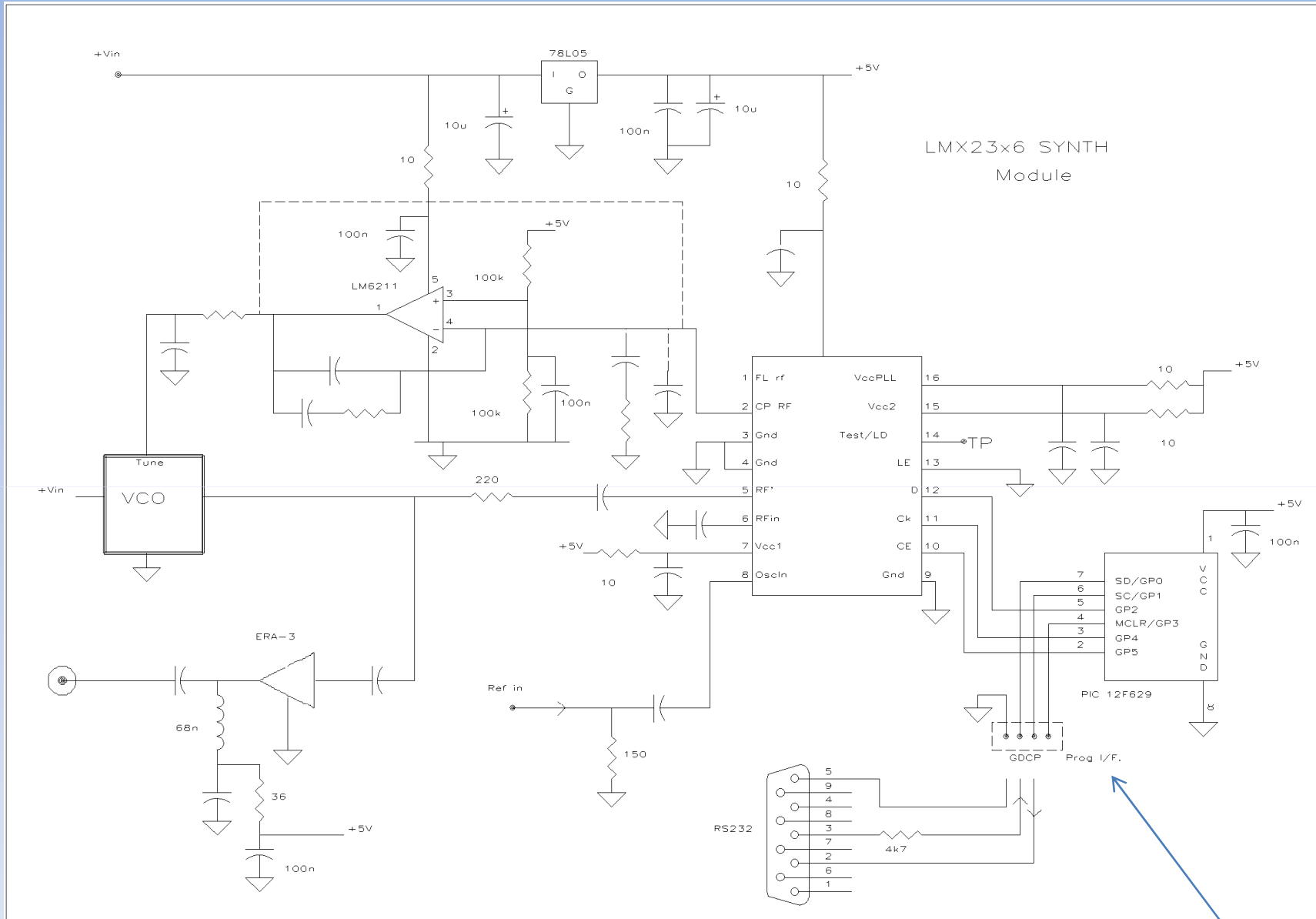
- LMX2326 is typical – and getting on a bit now!
- 100MHz to 2.6GHz input
 - R divider (R = 3 to 16383)
 - N divider (N = 32 to 262175)
 - Some flexibility for odd freqs
- $F_{out} = F_{ref} * N / R$
 - VCO Drive 0 – 5V,
 - Loop filter ~ 3 Caps, 2 Rs
 - LM6211 opamp Vtune > Vcc

The screenshot shows a software window titled "Freq Synth Factors" with the following parameters and results:

1700.4525	RF Source
3400.9049774	RF Output MHz
2	RF Multiplication
10	Ref. Input MHz
30	Minimum Fcomp kHz
100	Maximum Fcomp kHz

GO!

Ref / 221	Fvco / 37580
Fcomp 45.24887kHz	
Error -22.624Hz = -0.007* 10^-6	
R 0x00DD	N 0x92CC



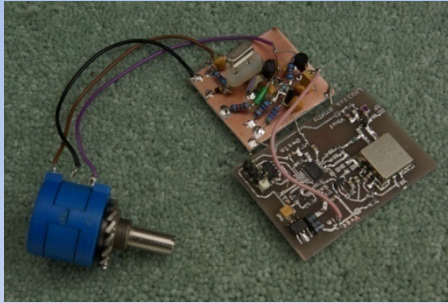
RS232 programming

Continuous Tuning

- Transverters for full tuning at IF
 - so a fixed LO is no problem
- Direct Conversion or fixed IF receivers give at most a few kHz, or no tuning at all.
 - So.....
 - We Need a tuneable LO at microwaves

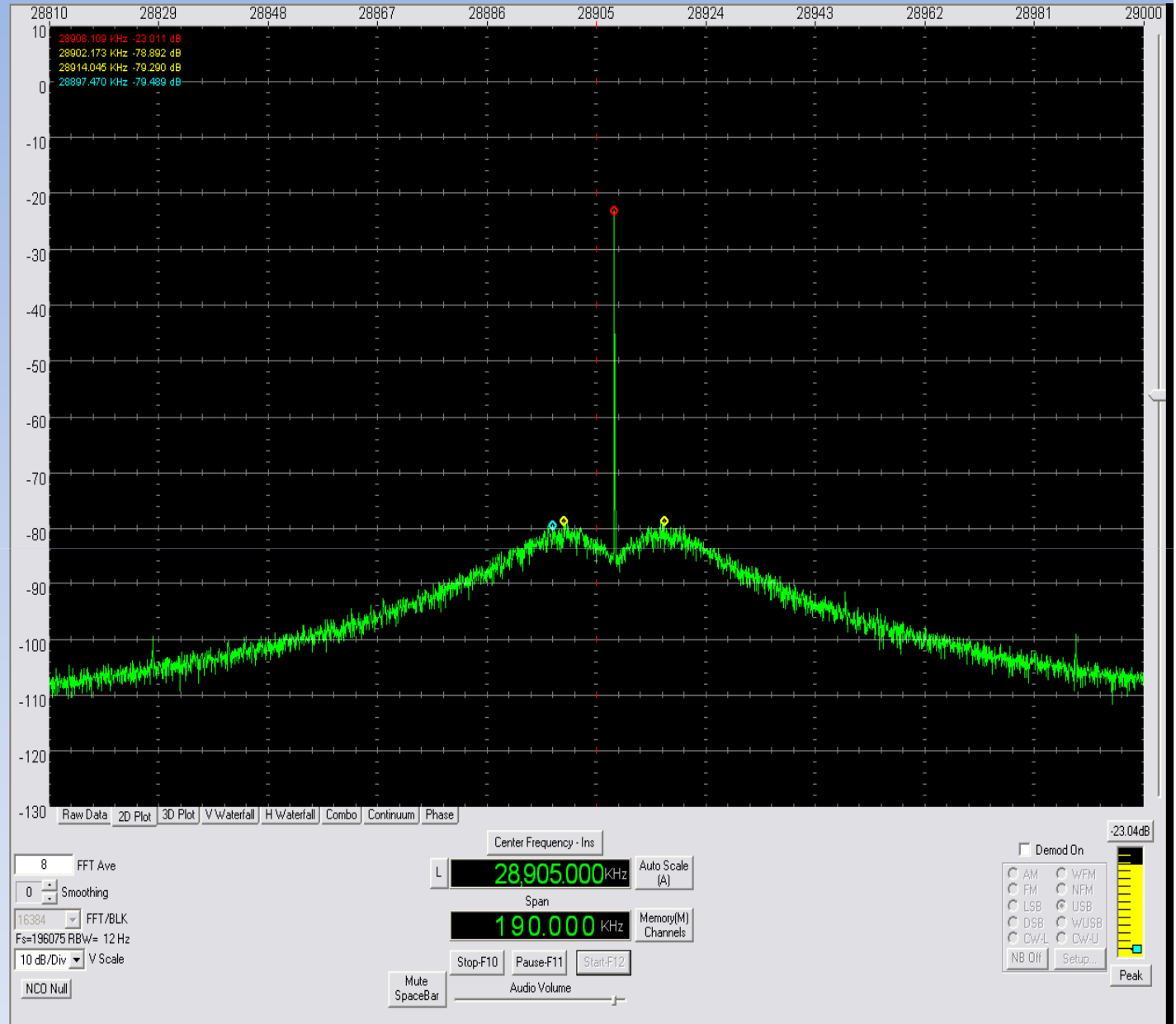
KISS

- Pull the synthesizer reference input
 - Typical $||$ resonant at 10MHz will pull 30 – 50ppm depending on wanted stability.
 - 100kHz at 2.3GHz, 400kHz at 10g
 - Ceramic resonator even more !
 - Play with R and N values. Any surplus crystal.
 - ‘Intelligent’ Freq counter display on Xtal freq.
- Low IF at 100kHz, RC tuned LO.
- These are NOT LOCKED ! IC202 equivalent
 - Use DDS as reference. Locked, but not too clean



Nominal Centre Freq **2320.9 MHz**
 Nominal Crystal **10 MHz**
 Pulling Range **40 +/- ppm**
 Approx Fref **454 kHz**
 Actual R **22**
 Actual N **5106**

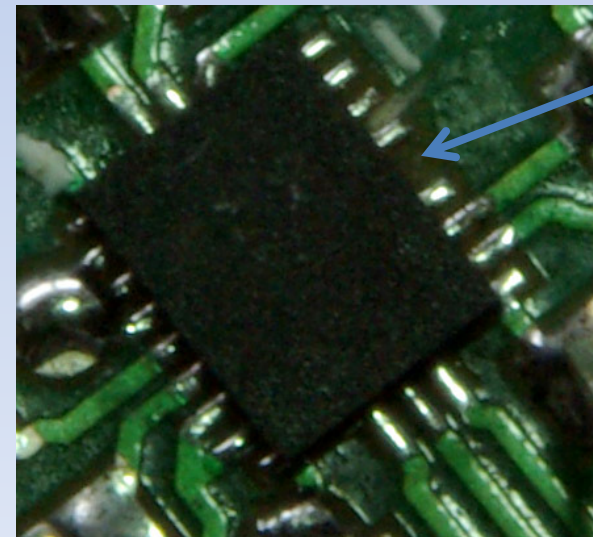
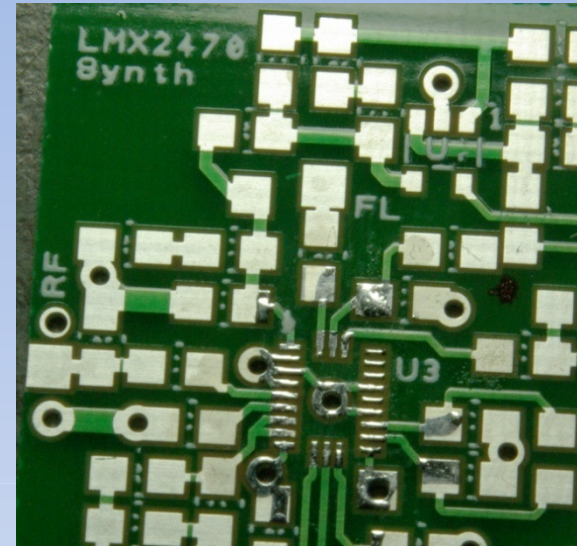
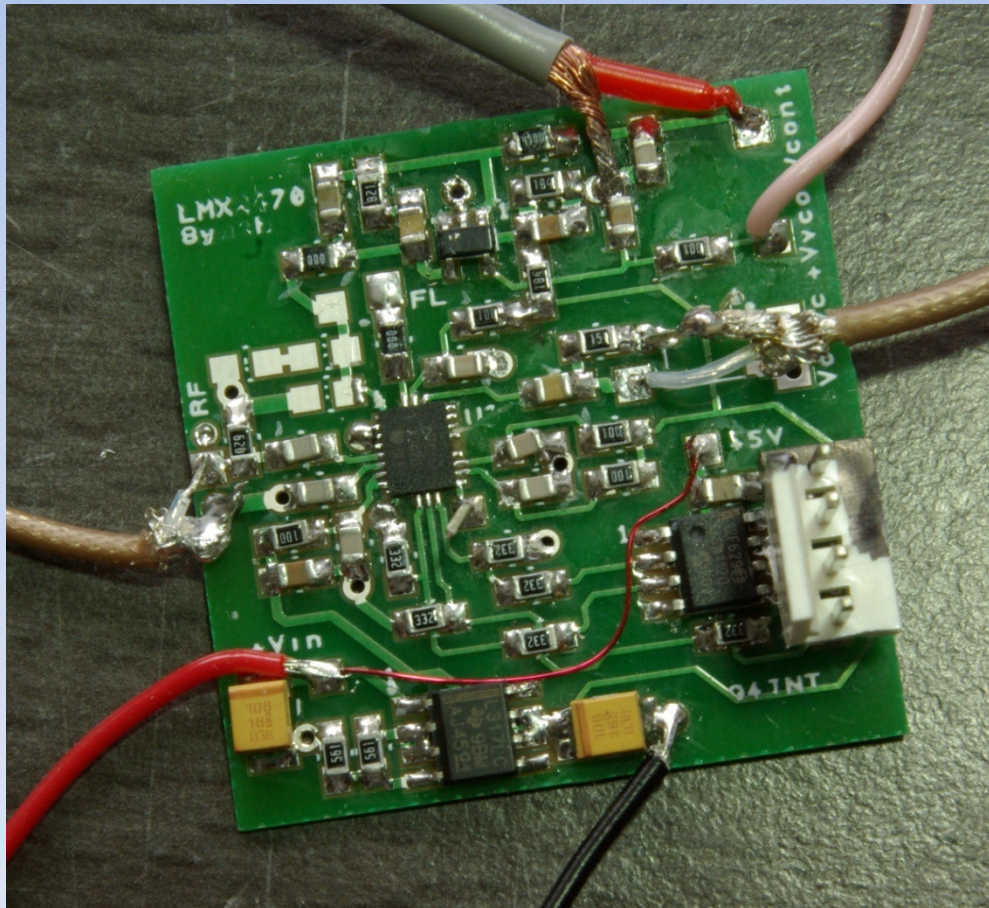
 Fmin **2320.8163 MHz**
 Fmax **2321.0019 MHz**
 Delta **185.67 kHz**



Fractional N Synthesizer

- Generate directly at GHz
 - LMX2470 to 2.5GHz, LMX2487 to 6GHz
- Locked to Master Reference input
- Tiny step size – few Hz
- $F_{out} = F_{ref} / R * (N + F / D)$
 - Let $R = 1$ for 10MHz ref (or X2)
 - $D = 1000000$ for 10Hz steps
 - Loop BW 30 - 100kHz for low cost VCO

LMX2470 Synth PCB



OOPS!

Data Modes

- Set tuning grid to the tone spacing
 - JT65c 10.7666Hz
 - JT4g 315Hz
- Send codes to change F register
- Standalone Beacon Source
 - Faster switching than RDDS
 - Accurate tone spacing at 10GHz and up

Phase noise and Spuri

- Always a problem with synths – isn't it?
 - BUT Is phase really an issue ?
 - We want narrowband signalling.
 - Any modern synth with $F_{ref} > 50\text{kHz}$ and loop BW $> 8\text{kHz}$ will “sound clean”,
 - Unnoticed on SSB or audio tones.
 - Strong signals / other stations nearby
 - Close in spurs typical -60 to -80dBc,
 - Big effort needed with contest stations
 - Make sure the reference input is clean

5Hz tuning grid at 2320MHz

LMX2470 Control

Remote programming for LMX2470 Synthesizer

Reference In MHz: 10

Rdivider: 1 Ref doubler

Fref = 10.0MHz

Fout MHz: 2320.905

Resolution / Grid Hz: 5

N = 232 F = 181000 D = 2000

Dithering

-Ve Phase Det

Charge Pump uA: 800

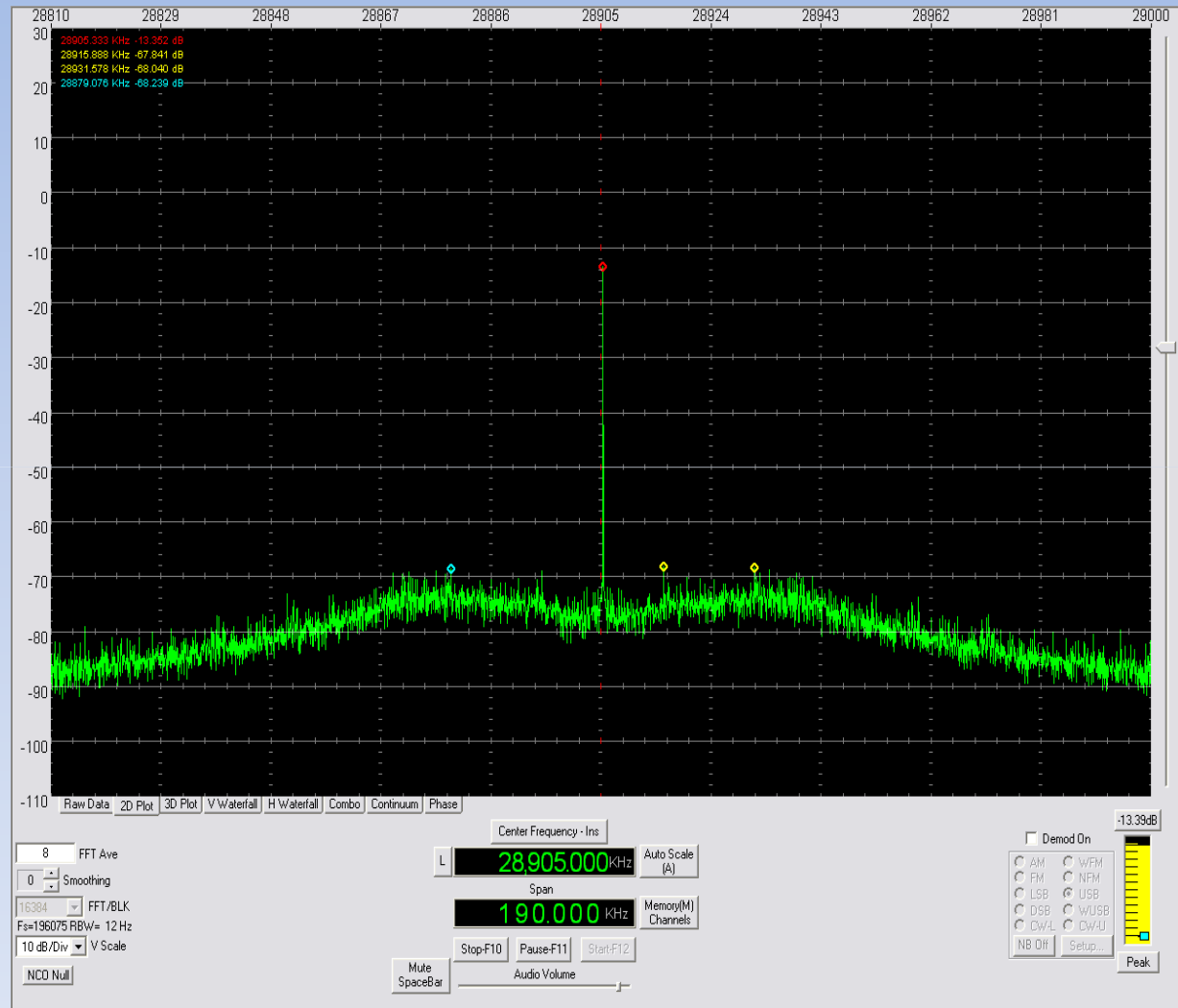
Set Register

Init from EE Set Freq

Update All Store to EE

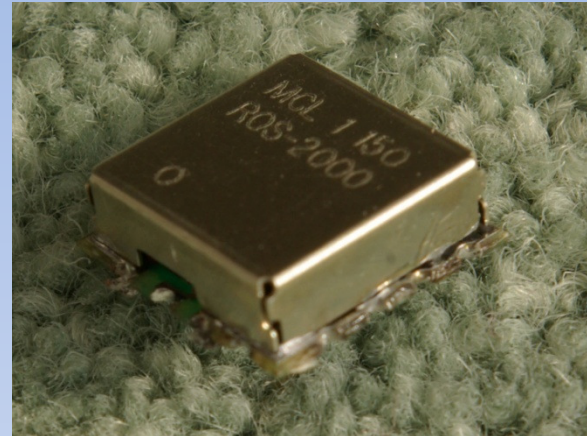
Response from Synth Module

```
0001 1101 0000 0110 0001 0000 0x1D0610
0100 0001 0100 1000 0000 0001 0x414801
1100 0000 0000 0111 0100 0011 0xC00743
0010 1000 0000 0000 0001 0101 0x280015
1011 1100 0010 1011 1100 0111 0xBC2BC7
0001 0000 0001 1111 0100 1001 0x101F49
0000 0000 1100 0100 1111 1011 0x00C4FB
0111 1010 0000 0010 1100 1101 0x7A02CD
```

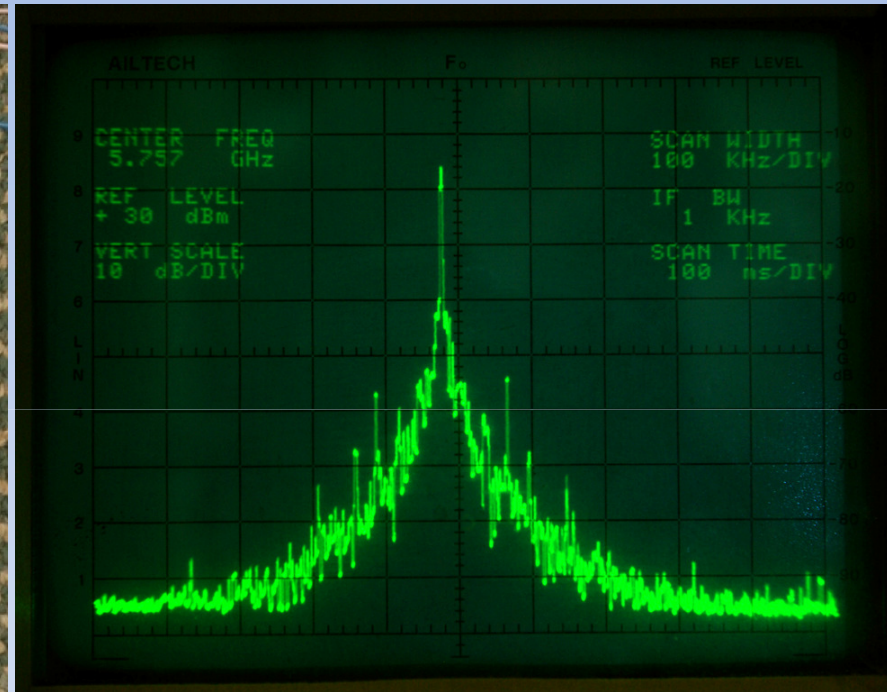
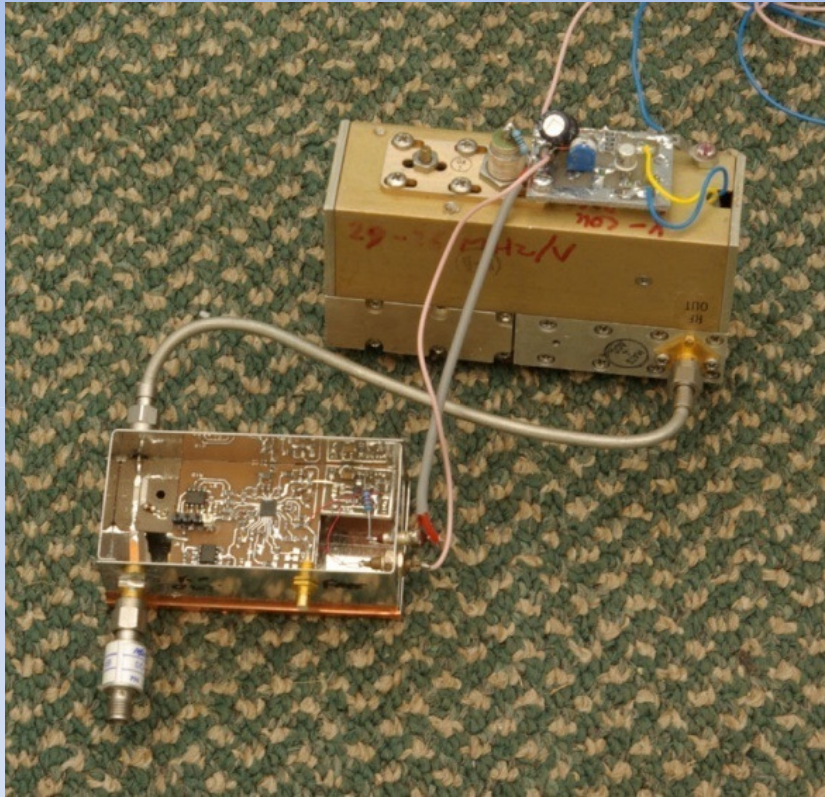


VCOs

- Minicircuits packaged –
 - low(ish) cost
 - Known spec, MHz/V
- Surplus
 - Old ‘Brick’ sources excellent 1.4 – 1.8GHz typical
 - Multipliers that are easily retuned
- Discrete
 - Some good designs wanted
 - Cavity / coax / stripline / LC



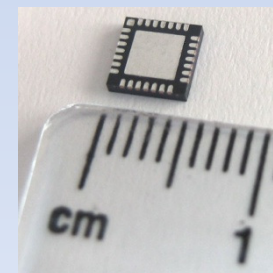
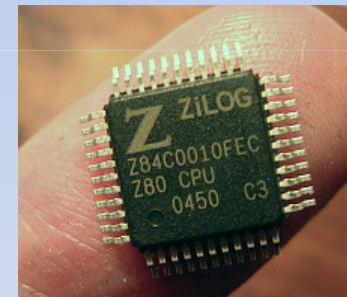
LMX2487 + 'Brick' LO at 5.76GHz



Discrete Spurii are on the
10MHz GPSDO reference
input.

The SMALL PRINT

- Surface Mount small components
 - SOIC 1.27mm pin spacing
 - TSSOP QFP
 - Thin-Shrink Small Outline Package, Quad Flat Pack)
 - 0.64mm pin spacing
 - Easily hand soldered (flux and wipe)
 - QFN (Quad Flat No leads)
 - LMX2470/ 87
- The PIN '0' bottom pad.



Soldering

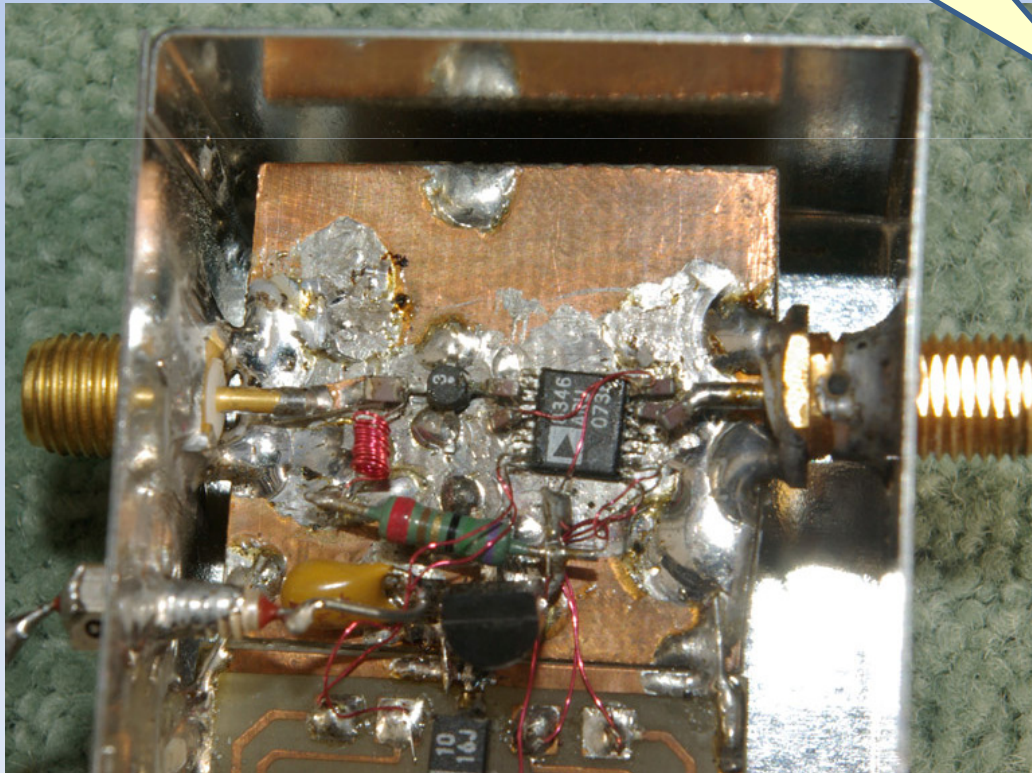
- Decent iron with small bit
 - Higher temp, solder flows better
- Separate flux
 - Prevents bridging
- Solder braid
 - Just In case
- Use leaded solder
 - Its going to be around for a long time yet

The Upside

- Robust chips
 - A lot better than earlier devices
 - Better static protection
 - Designed for higher soldering temperature
 - Never damaged one from handling – and that includes removal twice!

PCBs aren't Compulsory !

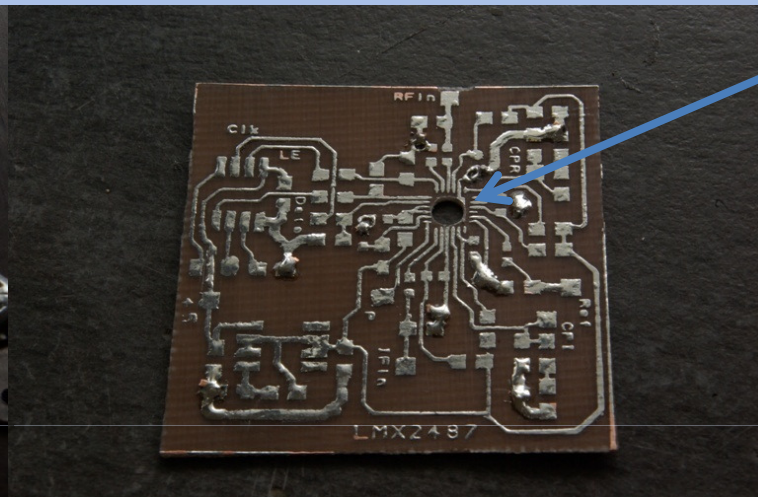
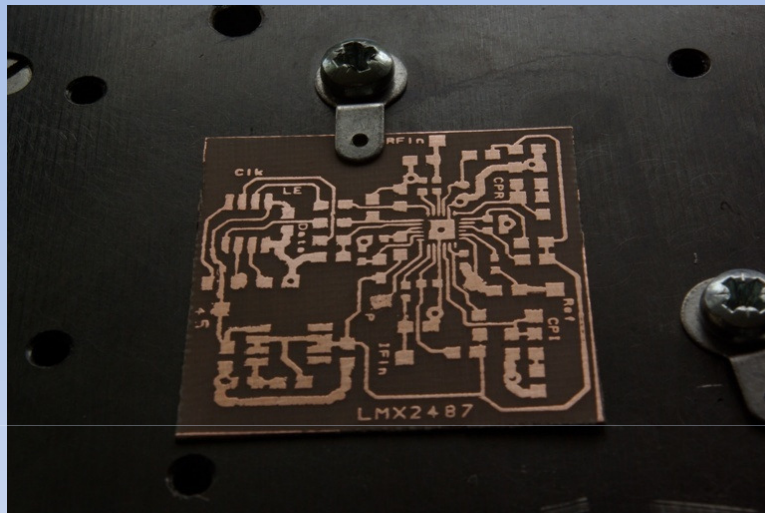
"Rats Nest"
Construction,
Please , NOT
"Birds Nest"



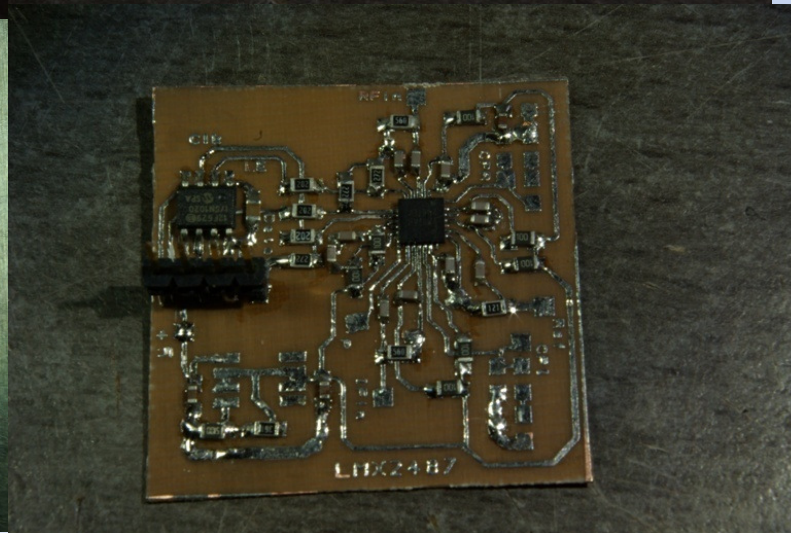
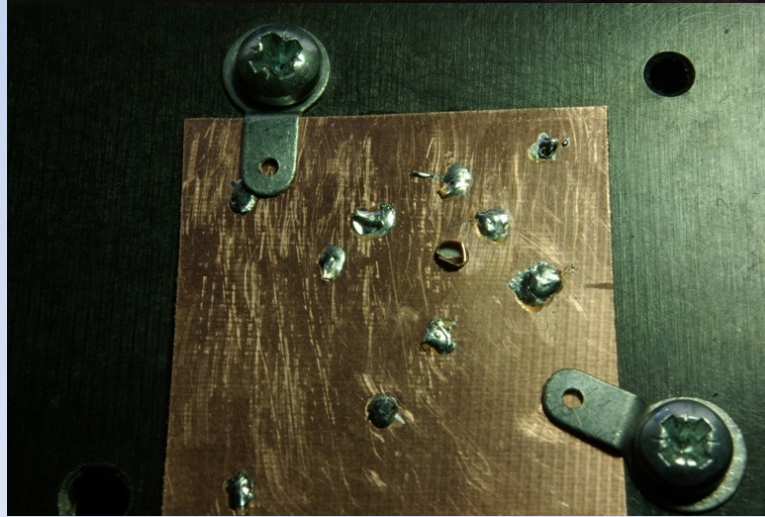
But PCBs do make life easier...

- Homebrew
- Laser printer and Press-N-Peel OR
- Acetate and UV light box
- Both will cope with TSSOP (0.64mm pin spacing)
- P-n-P OK with QFP (0.5mm pad spacing) for fract N synths
 - This is probably about the limit ?

Homebrew PCBs



Pin 0



Other Skills

- Synth chips want serial programming –
 - PIC interface
- Plenty of code already out there to do the job
 - **GET or make a PIC programmer and at least be able to blow your own devices from published code.**
- **BETTER STILL**
 - Assemble code from published sources
 - Do your own customisation, callsigns, frequencies

‘JNT PIC “Operating System”

- Each synth chip needs custom serial programming
- Small 8-pin 12F629 PIC with standardised set of connections
- RS232 serial programming
 - instant self-boot at turn on
- Easy access to synth-chip registers
- Some customised driver code

Driver Progs

LMX23x6 Control

Remote programming for LMX23x6 Synthesizer

Fcomp kHz: 454.454! R Register: 0016
 Reference MHz: 10 Set R

Fout MHz: 2320.905 Set N: 413F3
 N Register

F Register: 00010 Set F

LD Test Pin: Rdiv Ndiv Dig Lock Det
 -Ve Phase Det Charge Pump 1mA

Update Store to EE COM1 9600 baud

Response from Synth Module

```
F-00010
jjjLMX23x6 Control G4JNT
Commands:
Rxxxx
Nxxxxx
Fxxxxx
[U]pdate
[W]rite EE

R 0016
N 413F2
F 00008
```

Non-integer division needed
 Freq error-5639Hz

Talk to PIC OS. /
 Synth on Serial
 Interface

LMX2470 Control

Remote programming for LMX2470 Synthesizer

Reference In MHz: 10
 Rdivider: 1 Ref doubler
 Fref = 10.MHz

Fout MHz: 2320.905 +
 Resolution / Grid Hz: 5 -
 N= 232 F= 181000 D= 2000

Dithering
 -Ve Phase Det
 Charge Pump uA: 800 Set Register

Init from EE Set Freq Send
 Update All Store to EE

Response from Synth Module

```
0001 1101 0000 0110 0001 0000 0x1D0610
0100 0001 0100 1000 0000 0001 0x414801
1100 0000 0000 0111 0100 0011 0xC00743
0010 1000 0000 0000 0001 0101 0x280015
1011 1100 0010 1011 1100 0111 0xBC2BC7
0001 0000 0001 1111 0100 1001 0x101F49
0000 0000 1100 0100 1111 1011 0x00C4FB
0111 1010 0000 0010 1100 1101 0x7A02CD
```

Freq Synth Factors

1700.4525 RF Source
 3400.9049774 RF Output MHz
 2 RF Multiplication
 10 Ref. Input MHz
 30 Minimum Fcomp kHz
 100 Maximum Fcomp kHz

GO!

Ref / 221 Fvco/ 37580
 Fcomp 45.24887kHz
 Error -22.624Hz = -0.007* 10^-6
 R 0x00DD N 0x92CC

MC145170 Synthesizer Control G4JNT

Remote programming for VHF synthesizer modules running "MC145170CTL" software.

Fcomp kHz: 200 R Register: 0032
 Reference MHz: 10 Set R

Fout MHz: 116 Set N: 0244
 N Register

C Register: 23 Set C

Phase Detector: PW/PhR PDout Invert PD
 Options: Fv Enable Fr Enable LD Enable
 Ref Out

COM Port 1



Questions