Chinese Microwave Synthesiser PCBs Using ADF4351 and the ADF5355

Brian Flynn GM8BJF

Overview of Talk

- Brief review of PLL chips with integrated VCOs.
- Look at what is readily available.
- Background on Int and Frac-N PLLs.
- How to use these chips.
- Overcoming some of the weaknesses of the Chinese PCBs.
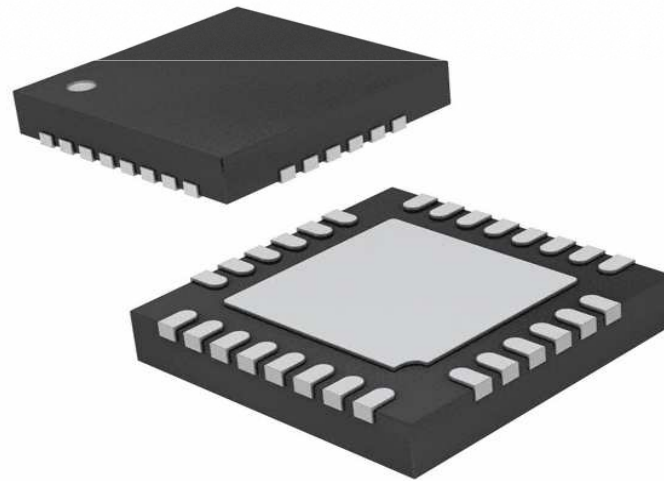
Synthesiser Chips with on-chip VCOs

- Over past six years a number of frequency synthesisers have become available with on-chip VCOs operating in the microwave region of the spectrum
- These make the implementation of microwave signal sources relatively straight forward
- There are some drawbacks (of course!)
- This talk will look at these and discuss ways round them.

Synthesiser Chips with on-chip VCOs

- Analog Devices ADF4350, ADF4351
  - 35 MHz to 4.3 GHz and 54 MHz to 13.6 GHz.

- Analog Devices ADF5355 and ADF5356
  - 54 MHz to 13.6 GHz.

- TI LMX 2541 (Ex Nat Semi)
  - 31.6 MHz to 4.0 GHz

- Linear Technology LT6948 (Now AD)
  - 37 MHz to 6.39 GHz

Chip packages

- Typically these chips are packaged in 32-pin Lead Frame Chip Scale Package [LFCSP] package and are difficult to solder.

Fortunately they are available from China on Ebay

Chinese ADF5355 PCB

Chinese ADF4351 PCB

Int-N and Frac-N PLLs

- These chips use Fractional-N PLLs
- Allows very small tuning steps
- Allows the use of much higher phase detector frequencies.
- Can give better phase noise (PN) performance.
- What is the difference between Frac-N and Int-N ???

Basic Int-N PLL

$$Fout = N . Fref$$

$$Fout = 1, 2, 3……. n . Fref$$

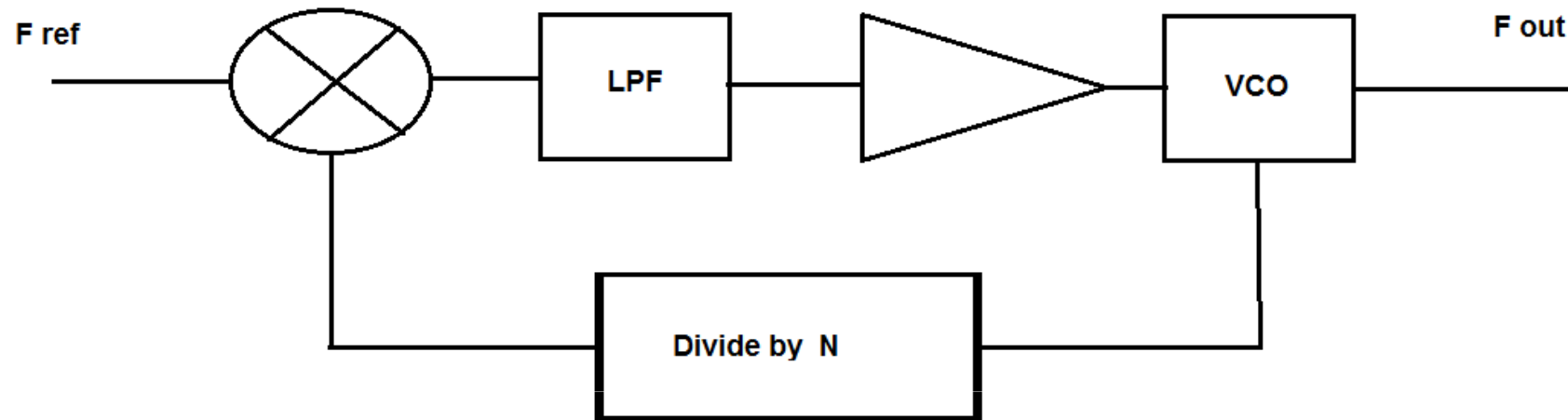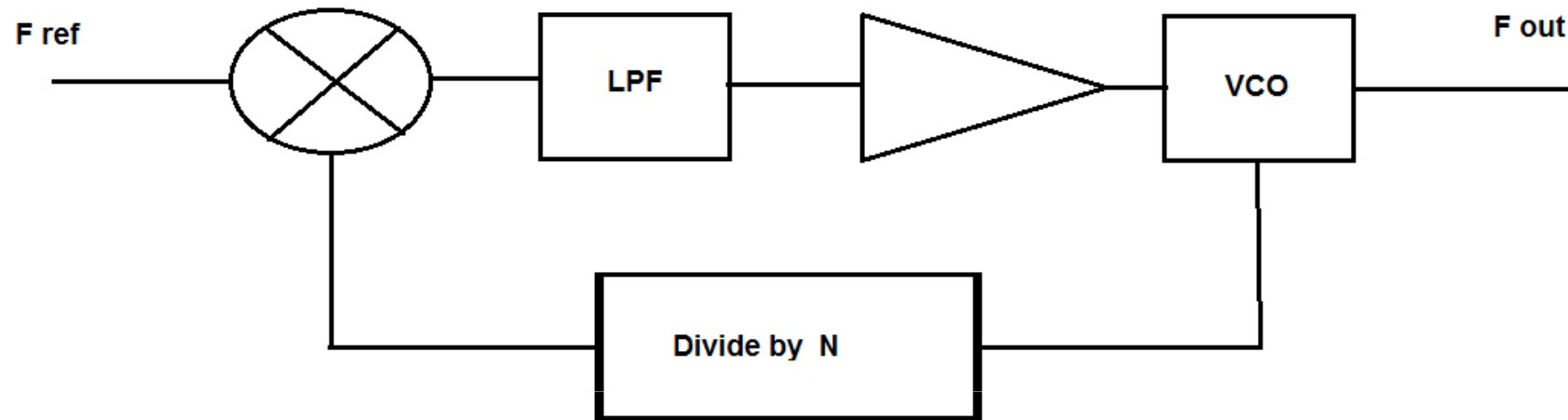If N is an integer minimum step size of $Fout$ is $Fref$

Frac-N PLL

$$Fout = N . Fref$$

N need not be an integer and can be a fractional number. This opens up useful possibilities for the design of the PLL.
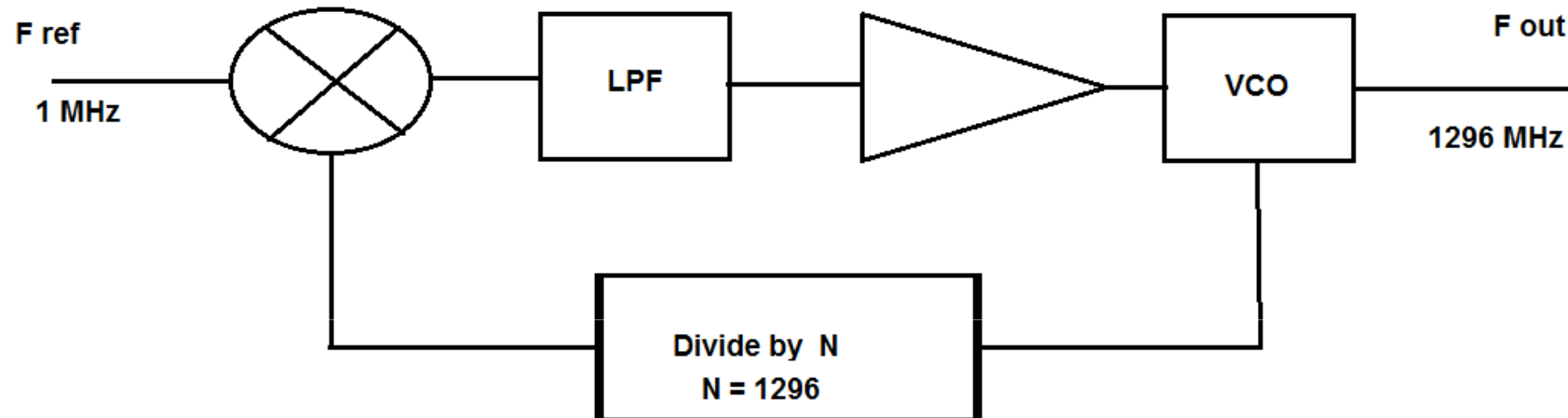
Integers and Fractional Numbers

- Integers are "whole" numbers, 1, 2, 3, 4... etc
- Fractional numbers are whole numbers with a fractional part, like $2\frac{1}{3}$ or more generally

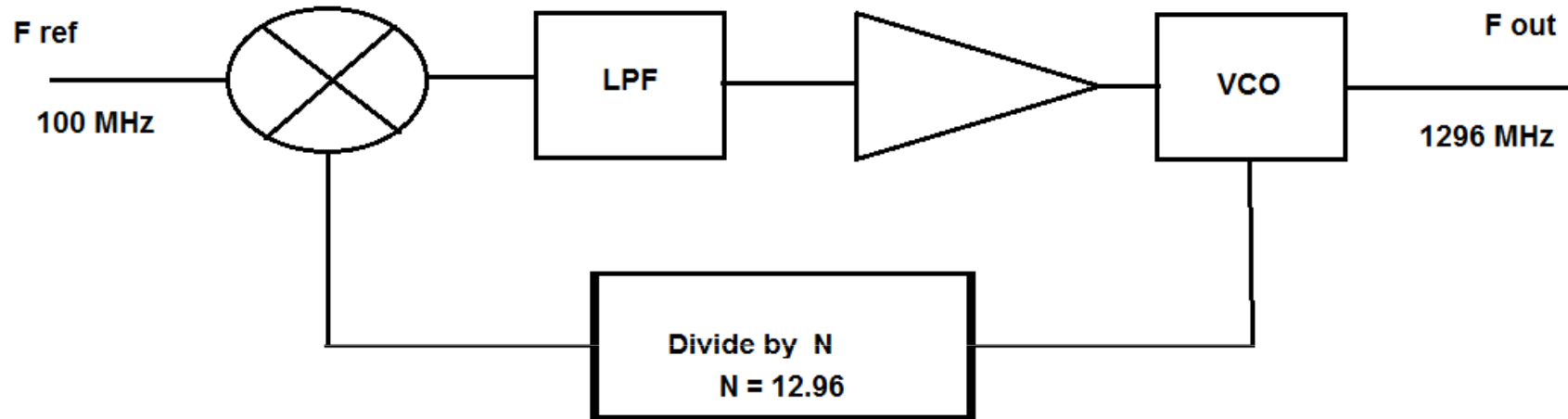- $N = INT + \dfrac{FRAC}{MOD}$

Fractional-N possibilities

- Can use a higher PFD frequency.

- N can be made a much smaller number.

- Less multiplication of phase noise on reference frequency.

- Useful for PLLs at microwave frequencies.

- Potential for better phase noise performance.

- Allows smaller tuning steps than Int-N.

Int-N PLL Numerical example

# Frac-N PLL Numerical Example

Implementation of Fractional Divider

- Digital dividers are inherently work with "whole" numbers

- To implement fractional division the divider chain is hopped between two adjacent integer division ratios

- In the foregoing example of N = 12.96 it would divide by 12 and 13, spending 4% of the time dividing by 12 and 96% of the time dividing by 13.
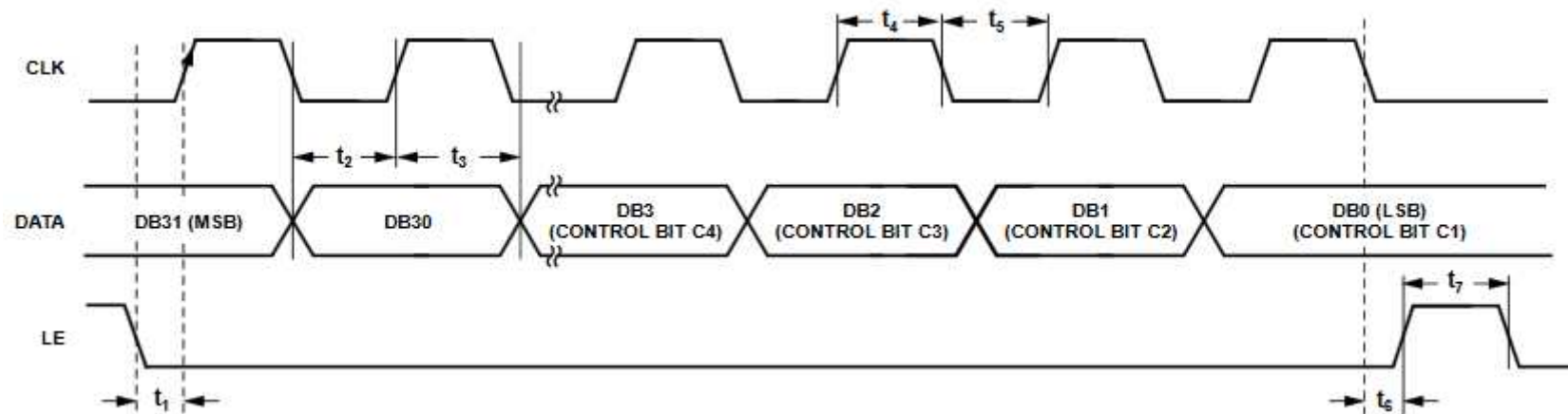
ADF4351 Block Diagram

ADF5355 Block Diagram
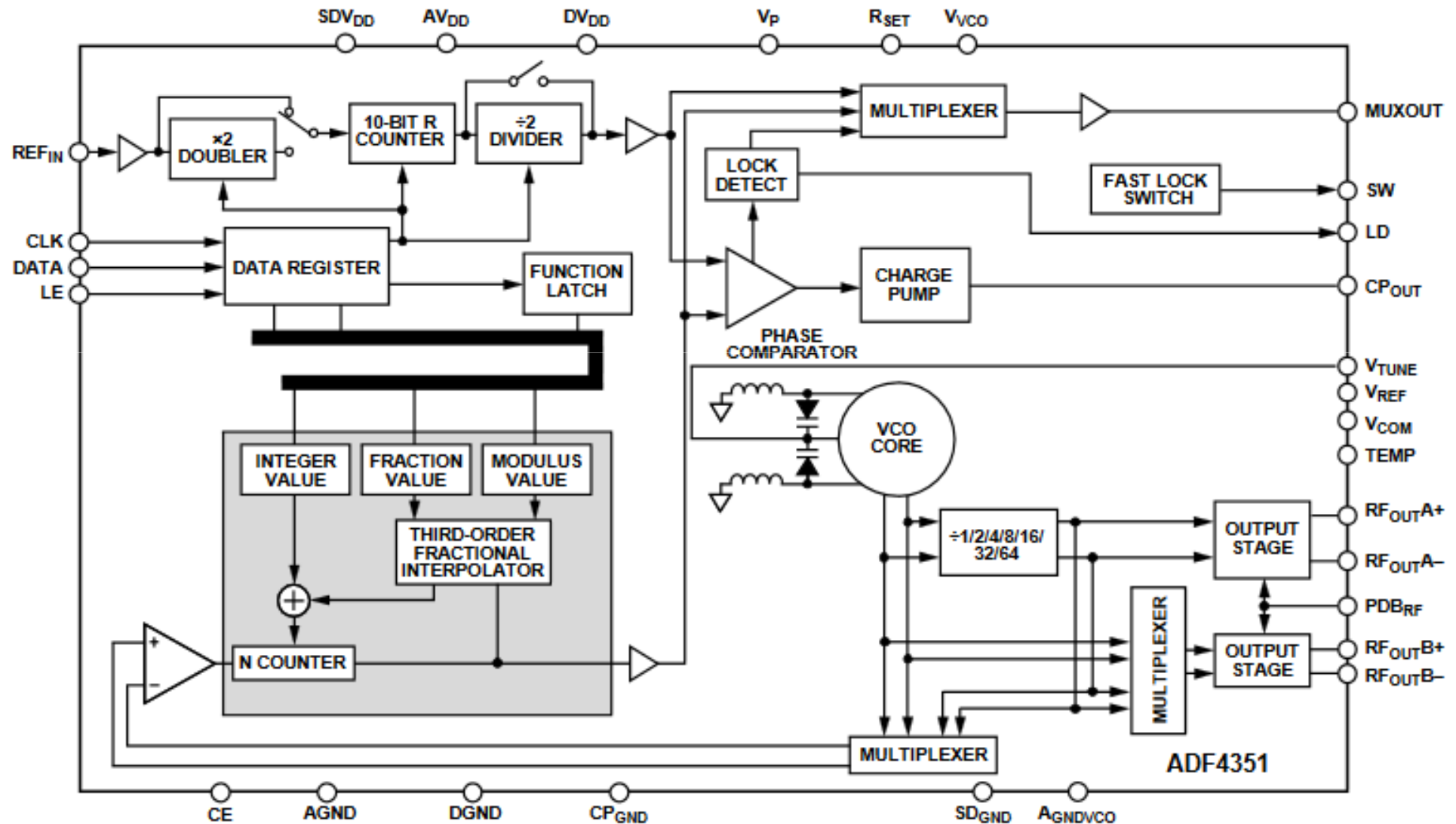
SPI Control Bus

- SPI bus is very standard for the control of ICs.
- A three wire system.
- Clock, Data and LE

PLL Programming

- ADF4351 has 6 x 32 bit registers to program
- ADF5355 has 13 x 32bit registers to program
- These registers set the frequency, power output, charge pump current etc
- Different approaches are to use Arduinos, PICs or the manufacturers free demo software running on a PC.

Demo software

Demo Software

- Strongly recommend this for getting to know these devices.
- Allows "tweaking" the settings for best performance.
- Designed to go with the demo boards which have a USB interface.
- Need a Cypress CY7C68013A board to do this.
- Fortunately these are only about £5!!

Cypress CY7C68013A USB2.0 Board

Cypress CY7C68013A USB2.0 Board

- Need to programme the board with the VID/PID for the AD demo board to fool the PC into thinking it has a real demo board connected so software can run.

- Details at https://gm8bjf.joomla.com/articles/9-pc-control-of-analog-devices-adf4xxx-synthesiser-chips

Phase Noise

- One problem with the low cost Chinese boards is phase noise.

- The RF output is contaminated by noise.

- Comes from poor quality power supply regulators on the boards.

- AD recommends the use of their ultra low noise regulators to power the ADF synthesiser chips.

Phase Noise

Schmatic for ADF4351 PCB

Schematic for ADF5355 PCB

C1 0.1uF C3 100pF AVDD C2 0.1uF C4 100pF GND GND

L2 3.9nH L3 3.9nH

OUT+ L6 1.9nH C6 1nF R3 0R OA+ R4 0R OA- C7 1nF L5 1.9nH OUT- GND

GND C8 100pF C5 0.1uF GND
DVDD L1 10uH REF- R8 0R GND

X1 1 NC VDD 6 / 2 NC O- 5 GND / 3 GND O+ 4 OSC_7050 GND

R5 0R C9 1nF C10 1nF REF-
R6 100 R10 0R C38 1nF C37 1nF R17 0R REF+
REF+ GND

R13 5.3k D3 LAMP GND DVDD R1 10k
GND GND CREG1 C32 0.1uF C34 10pF CREG2 C35 0.1uF C36 10pF GND GND

U1 ADF5355

CLK 1 CLK
DATA 2 DATA
LE 3 LE
CE 4 CE
AVDD 5 AVDD
VP5V 6 CP
CPOUT 7 CPOUT
GND 8 CPGND

EP CREG2 SDGND MUXOUT REFINA REFINB DVDD PDBRF CREG1
VBIAS 24 VREF
VREF 23 VCOM
RSET 22 R7 5 GND
AGNDVCO 21 VTURN
VREFVCO 20 TEMP VP5V
VREGVCO 19 VP5V
AGNDVCO 18 GND
VVCO 17 AVDD
AVDD 16

AGND VRF RFOUTA+ RFOUTA- AGND RFOUTB AGNDF
AVDD OA+ OA- GND

C40 10pF OB GND

VCC F1 500MA U2 VIN VO AVDD C39 L4 22uH DVDD
D1 IN4007 C33 22u C28 0.1uF SHD ADJ C29 0.01uF R12 3.3k
GND BYP 22uF
GND GND LT176X C31 22uF D2 LAMP
GND

CPOUT R9 430 VTURN
C11 33nF C12 1uF C13 6800pF
R11 68
GND GND GND

GND 10k R14 P1
PDRF 1 2 CLK R2 10k GND
MUXOUT 3 4 LE R16 10k
DATA 5 6 CE R15 10k DVDD
GND 7 8 GND
DVDD 9 10
Header 5X2

J1 1 VCC 3 2 GND

U3 VIN VO VP5V C20 10nF
SHD ADJ C30 22uF
C18 0.1uF GND BYP
GND GND LT176X GND

AVDD C14 100pF C15 100pF C16 0.1uF C17 0.1uF GND
DVDD C19 0.1uF C21 100pF GND
VCOM C22 0.1uF C23 10pF GND
TEMP C24 0.1uF C25 10pF GND
VREF C26 0.1uF C27 10pF GND

Title		
Size A4	Number	Revision
Date: 2017-5-25		Sheet of
File: F:\pjjj5\pjj\pjj\ADF5355\ADF5355.SchDoc		Drawn By:

Phase Noise

- Two possible solutions
- Use additional decoupling
- Use the AD ultra low noise regulators.
- ADM7150 – Noise performance is 10 dB better than the LT parts used on the Chinese PCBs.
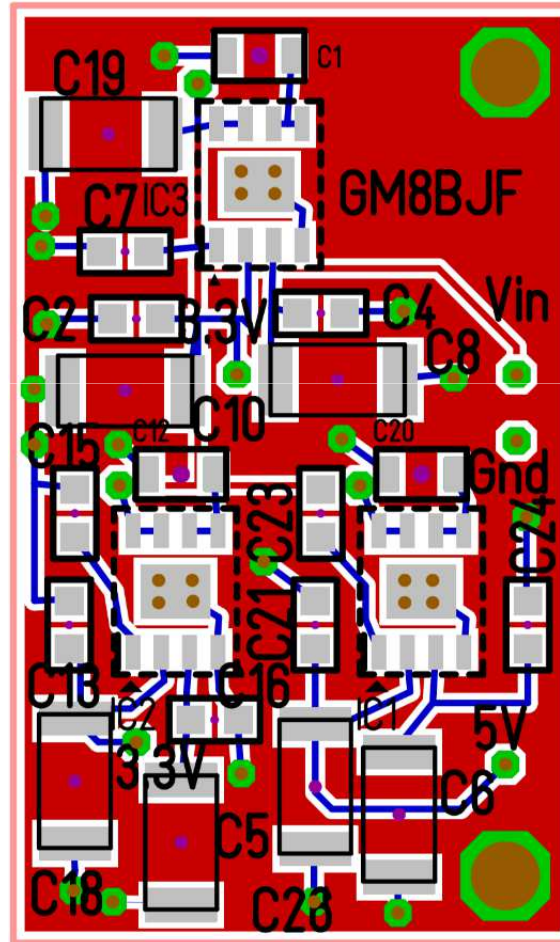- Package uses the dreaded "Pin 0" so need a custom PCB to make good use of them.
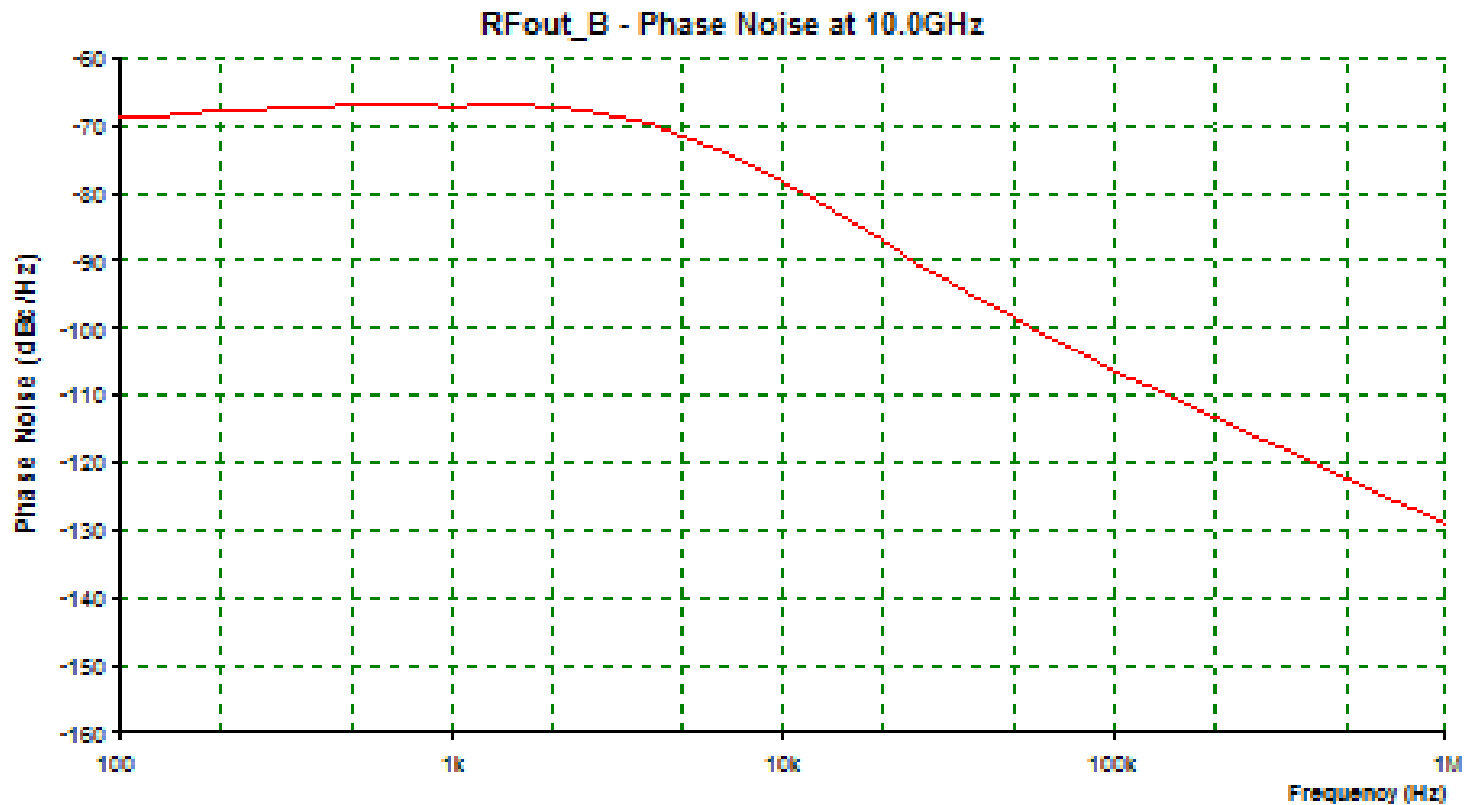
That's better!

Piggy Back Regulator PCB
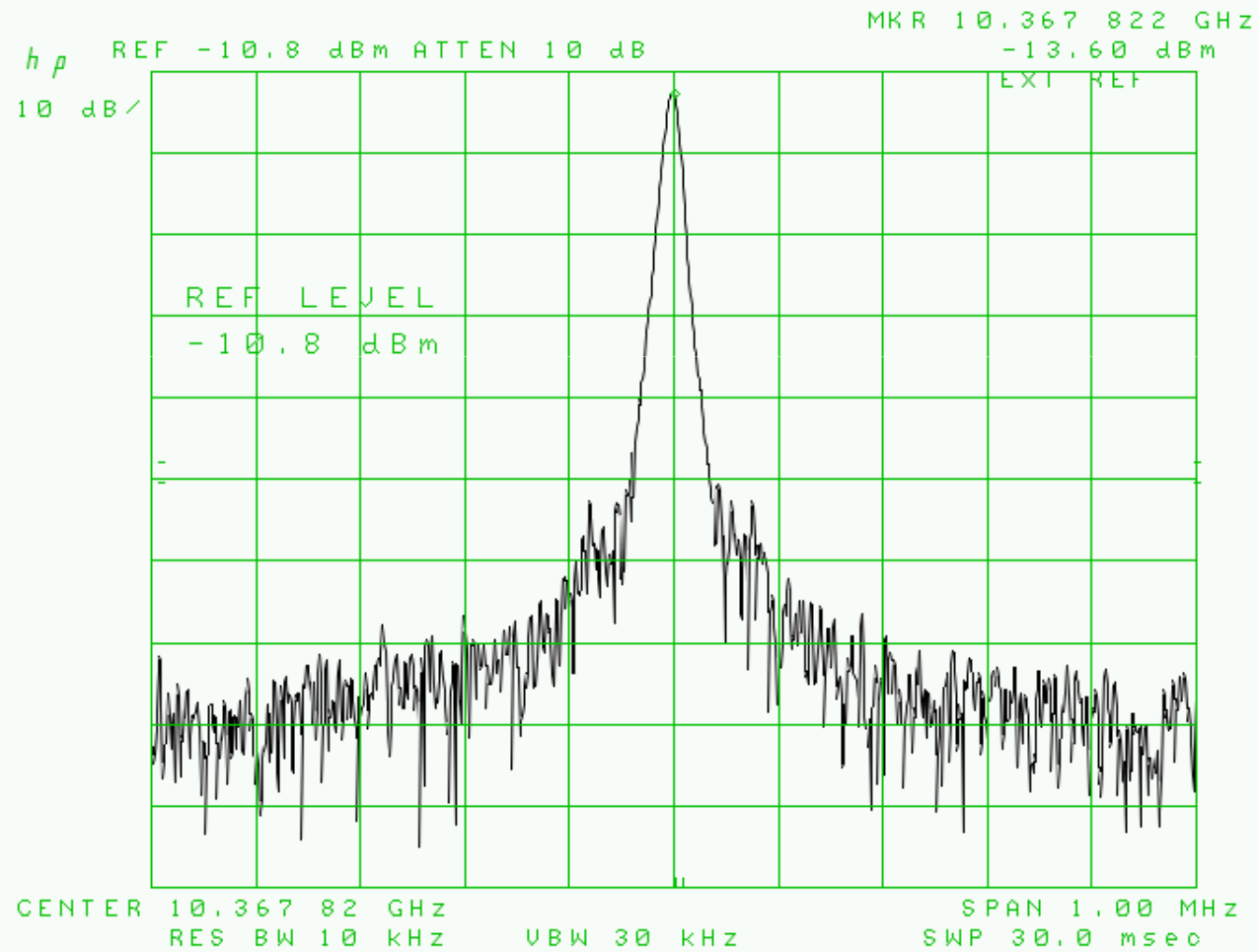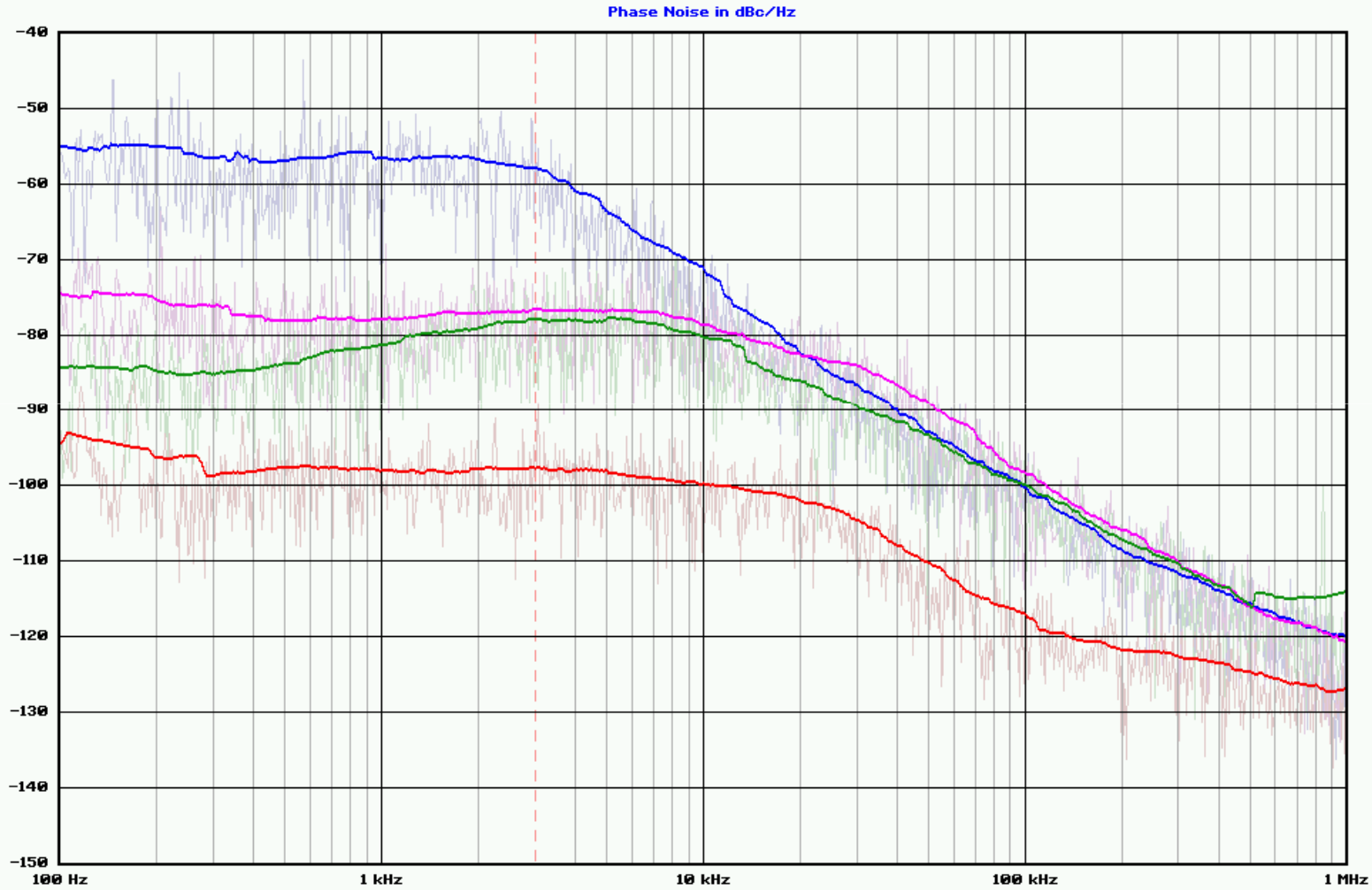
Regulator PCB

Simulated Phase noise at 10 GHz

RFout_B - Phase Noise at 10.0GHz

Phase Noise Plots

Trace	Carrier Hz	Carrier dBm	dBc/Hz at 3000 Hz	Time/Date	Instrument	Rev
adf5355 (Icp=0.3mA) vs CTI-Herley 12.575GHz	575 700 150	−11.20	−57.9	21/12/2017 17:38:14	HP8566B	2639
adf5355 (Icp=4.8mA) vs CTI-Herley 12.575GHz	575 701 250	−11.20	−76.5	21/12/2017 17:42:43	HP8566B	2639
11.6GHz DFS120 vs CTI-Herley 12.575GHz	975 499 000	−14.20	−77.7	21/12/2017 18:12:30	HP8566B	2639
Phase noise floor (100MHz Cal)	100 000 000	−11.20	−97.6	21/12/2017 17:50:26	HP8566B	2639

Applications

- Local oscillators
- Beacons
- Signal generators
- Test signals
- Weak signal sources
- Etc ...

Conclusions

- The Chinese PCBs offer a low cost RF source for microwaves.

- They need to be altered to get the best phase noise performance.

- The phase noise performance after modification is as good as the chips are capable of.