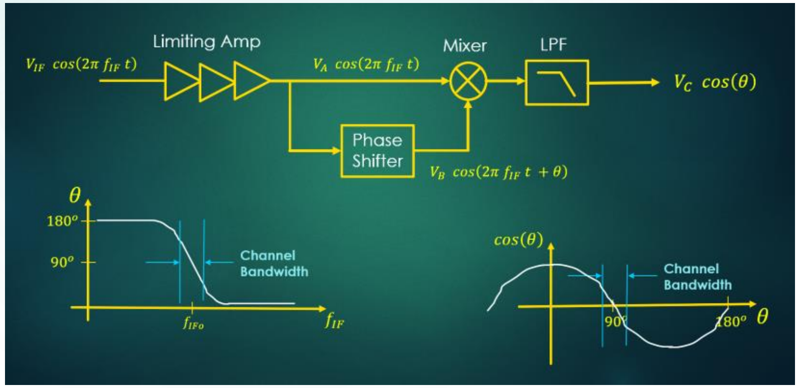
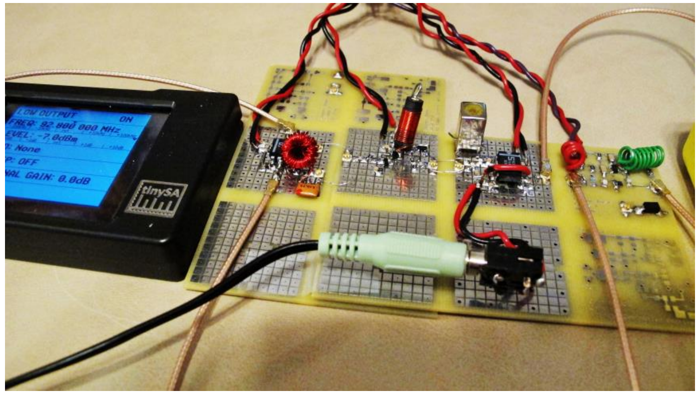
Radio Design 101
Episode 6 – Finishing the Receiver

Slides downloaded from: https://ecefiles.org/rf-design/
Companion video at: https://www.youtube.com/watch?v=jwbYQUTUEmE

In this episode we finish the receiver design by creating an IF amplifier and demodulator, and then assemble and demonstrate the final product. A limiting IF amplifier is used to address the 100 dB dynamic range of signals typical at a receiver's antenna input. The demod is a classic quadrature architecture that uses a mixer and phase shifter, and leverages what we learned in episode 5. Details of design, construction, and testing are presented, together with comments on how the overall Radio Design 101 course material is applicable to virtually all radio design work, including modern RF integrated circuits.

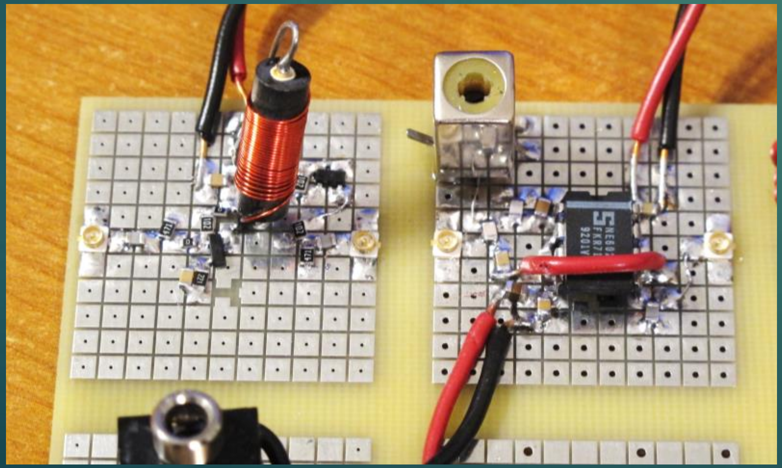


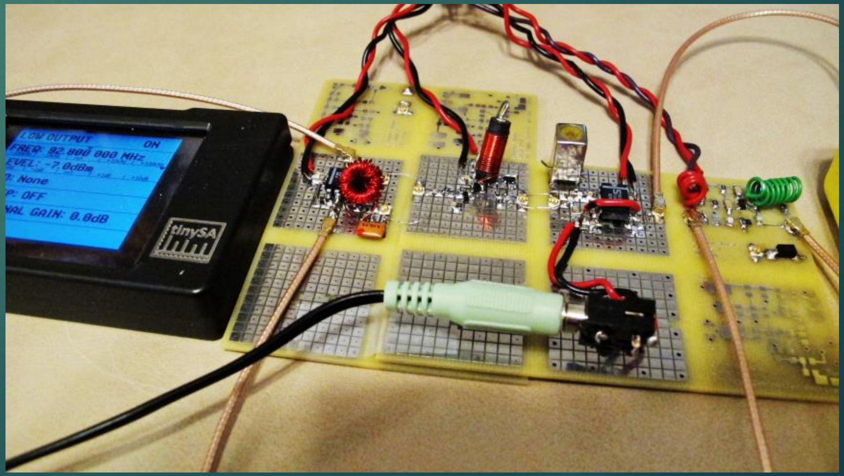


Radio Design 101

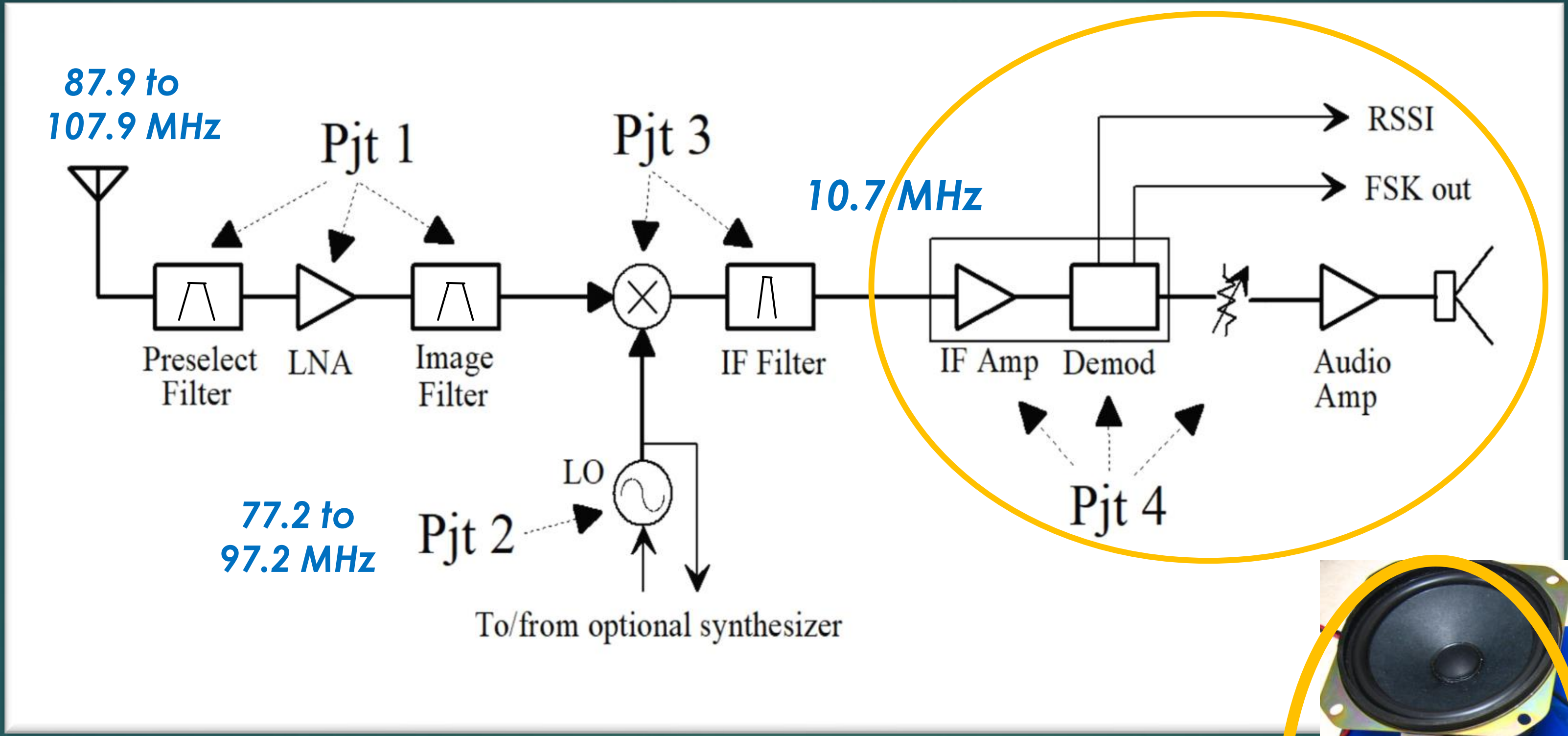
Episode 6

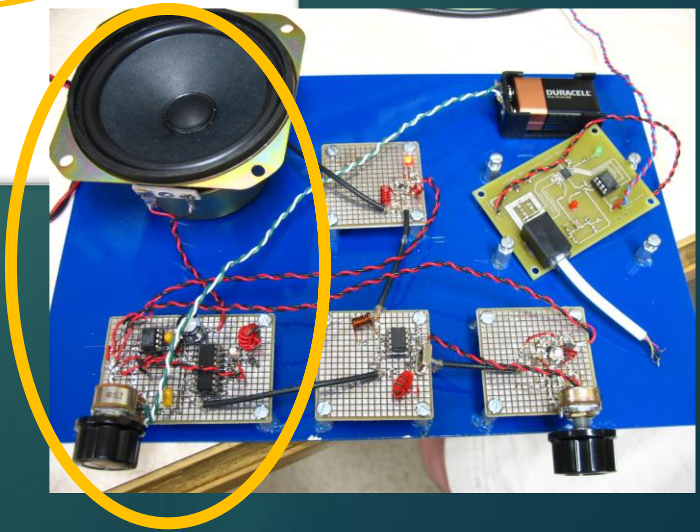
Finishing the Receiver





Class Projects





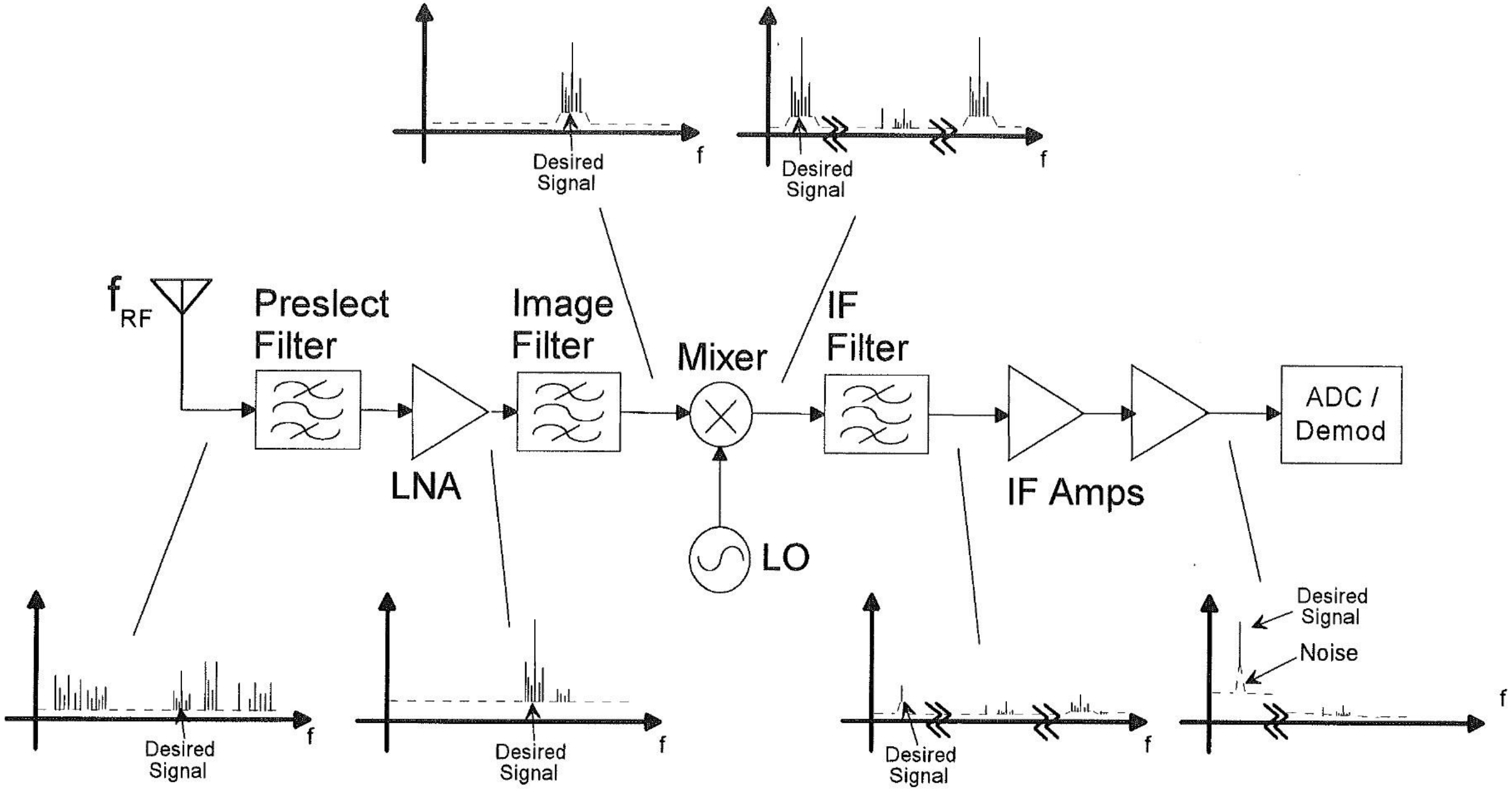
Pjt 4: IF Amplifier, Demod/Audio
(This Episode)

Debugging => Learning and Success

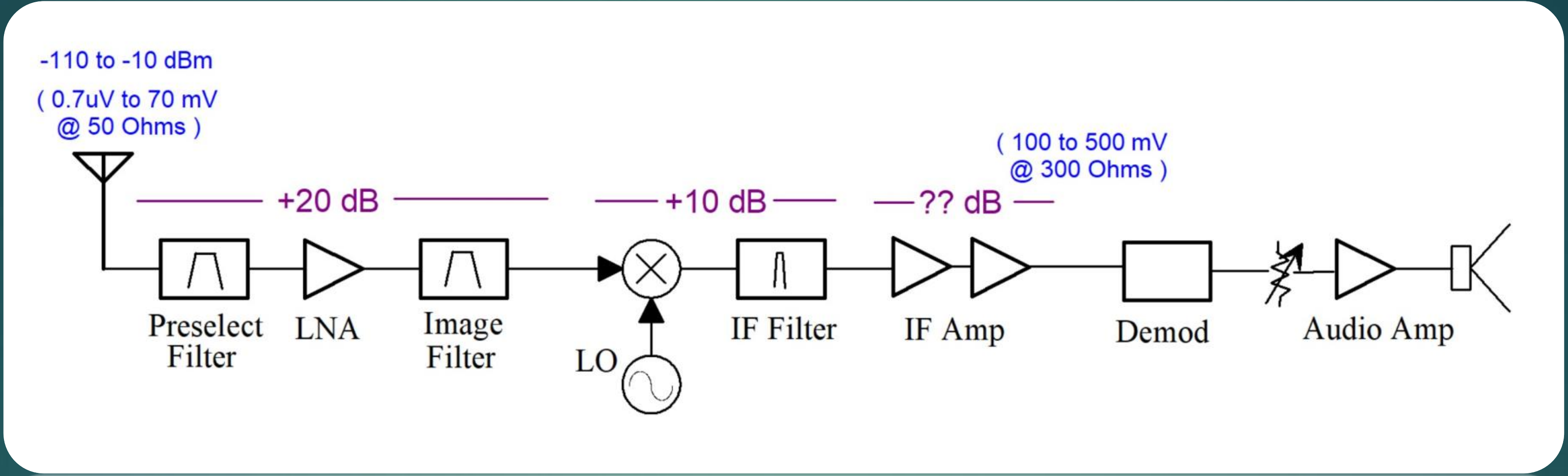
Today's Topics

- ***Superhet receiver architecture review***
- ***IF limiting amplifier design***
- ***Quadrature FM demod***
- ***Receiver assembly and demonstration***
- ***Modern radio chipsets***

Superhet Receiver Spectrums



Signal Levels and IF Amp Gain



Minimum IF Amplifier gain needed (with this frontend):

$$20log_{10}\left(\frac{100mV}{0.7uV}\right) - 20 - 10 - 20log_{10}\left(\sqrt{\frac{300}{50}}\right) = \underline{65\ dB}$$

Episode 6 Topics

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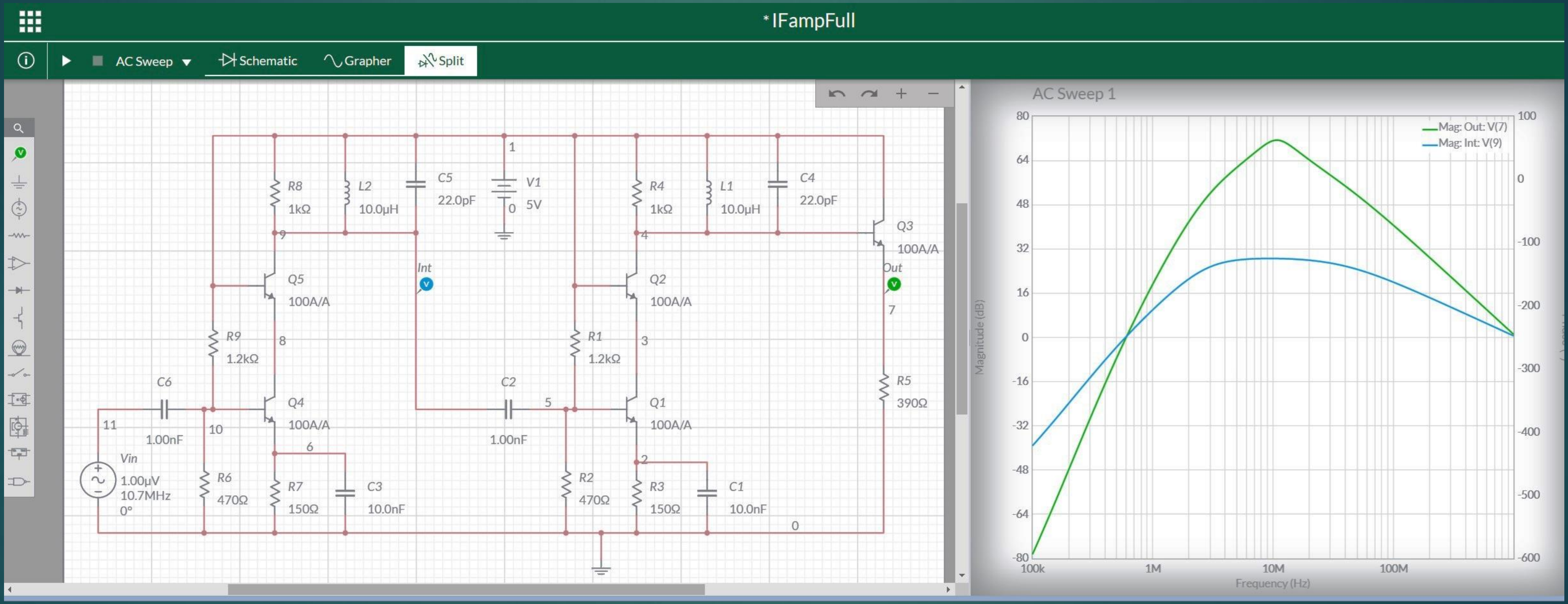
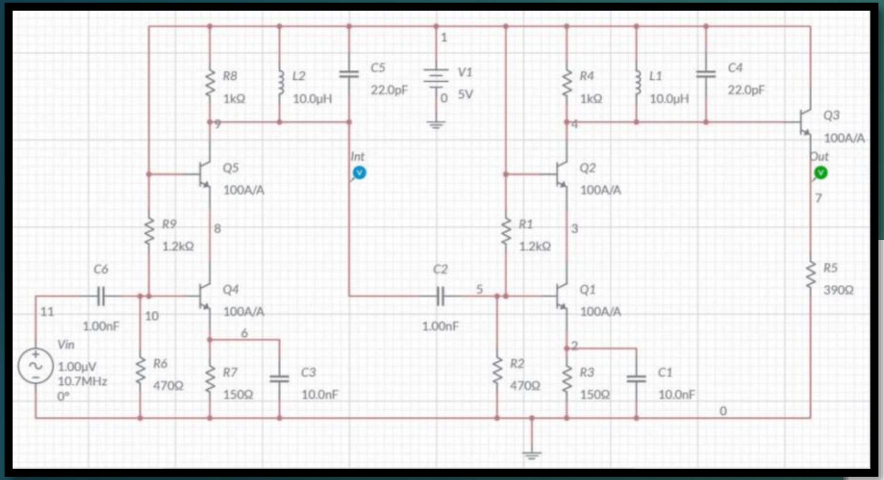
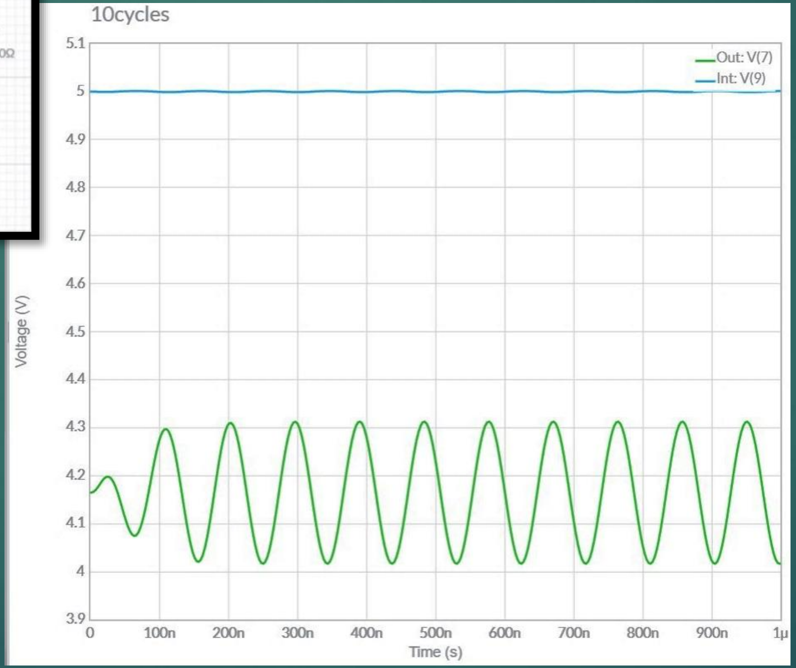
IF Amp Design and AC Sim

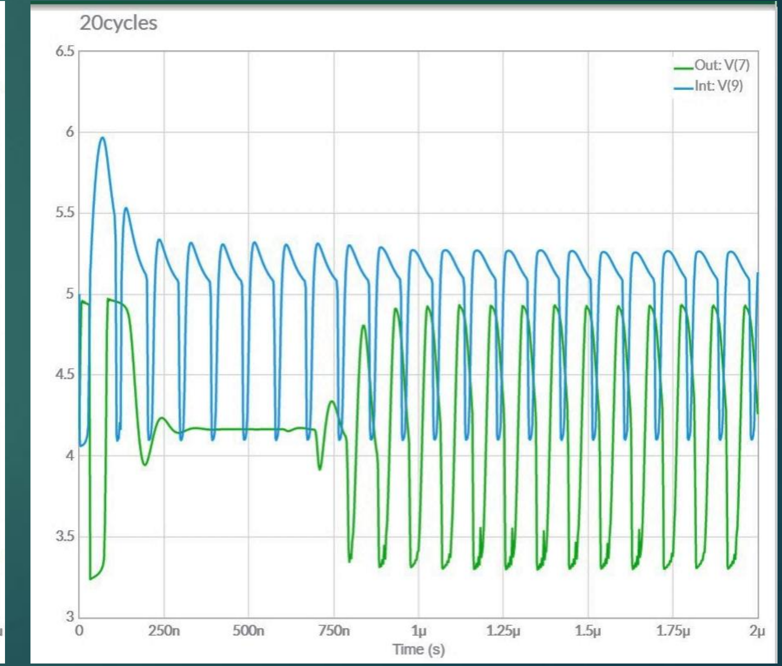


Drawn and simulated with free version of National Instruments' "***Multisim Live***" web-based tool

Transient Analysis and Limiting



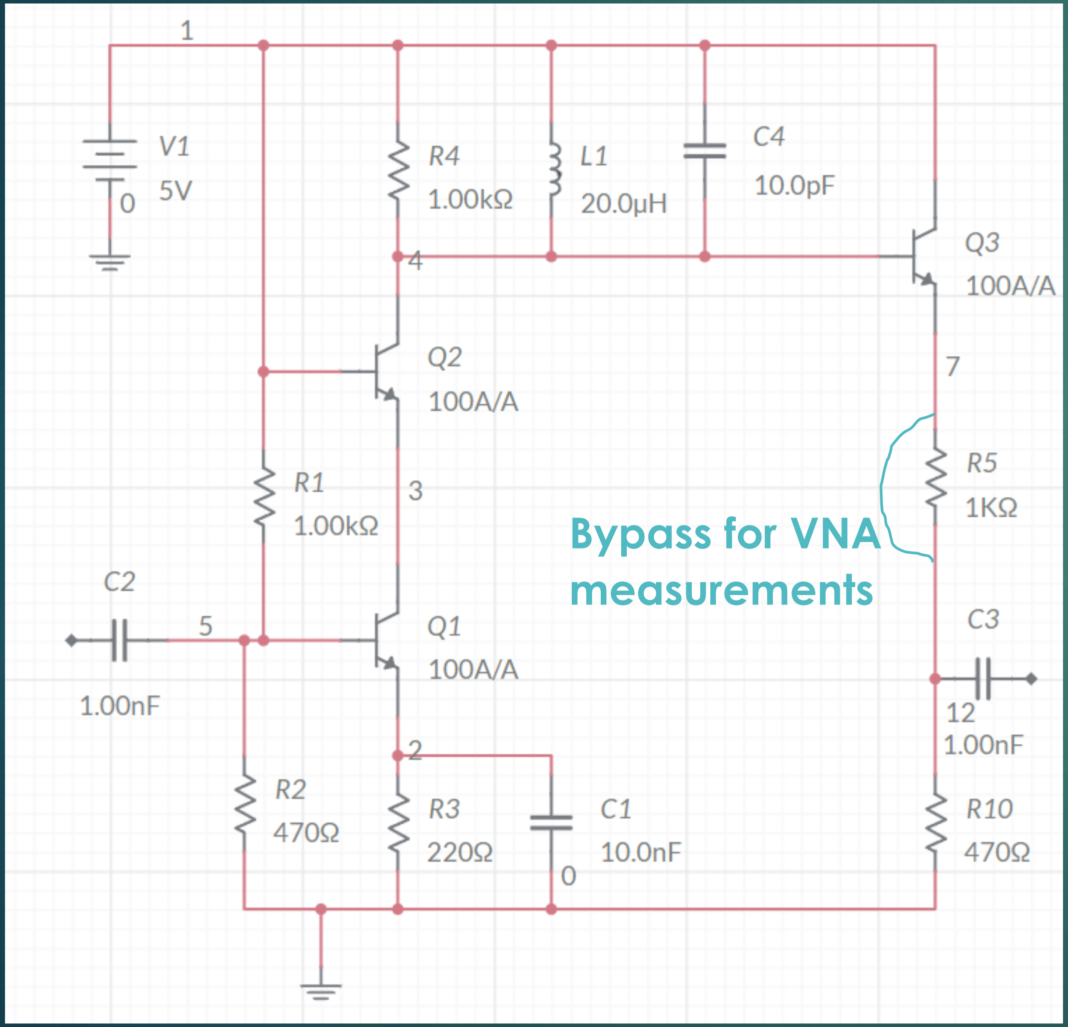


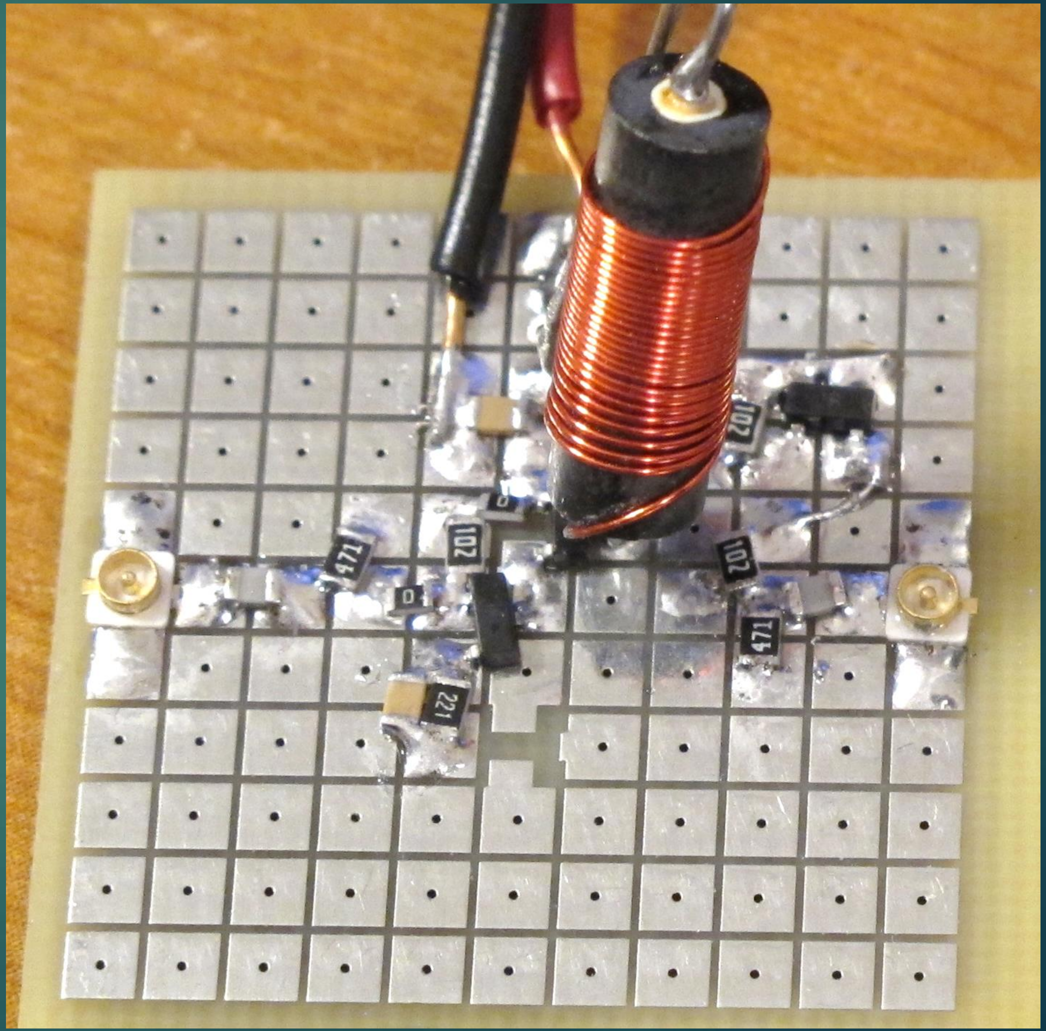


40 uV Input

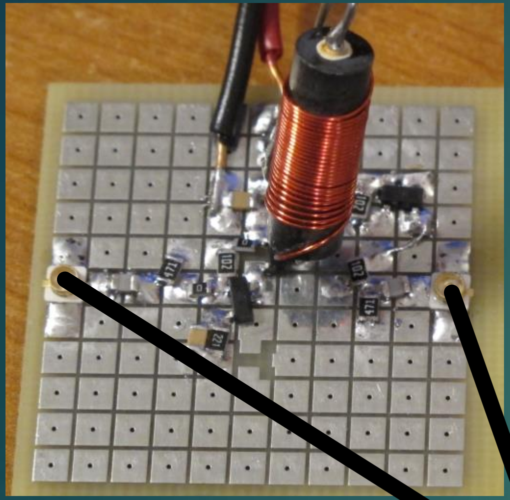
1.0 V Input

Construction (2nd Stage Only)

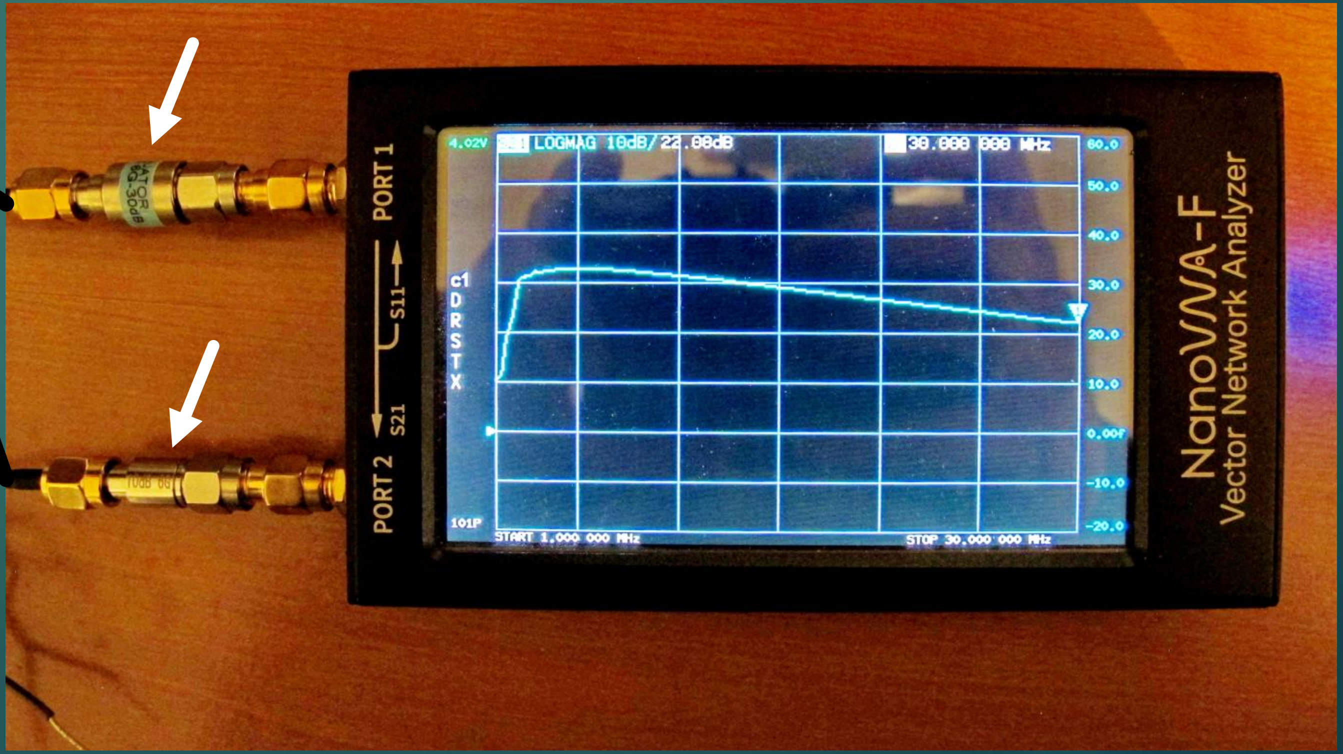




Testing

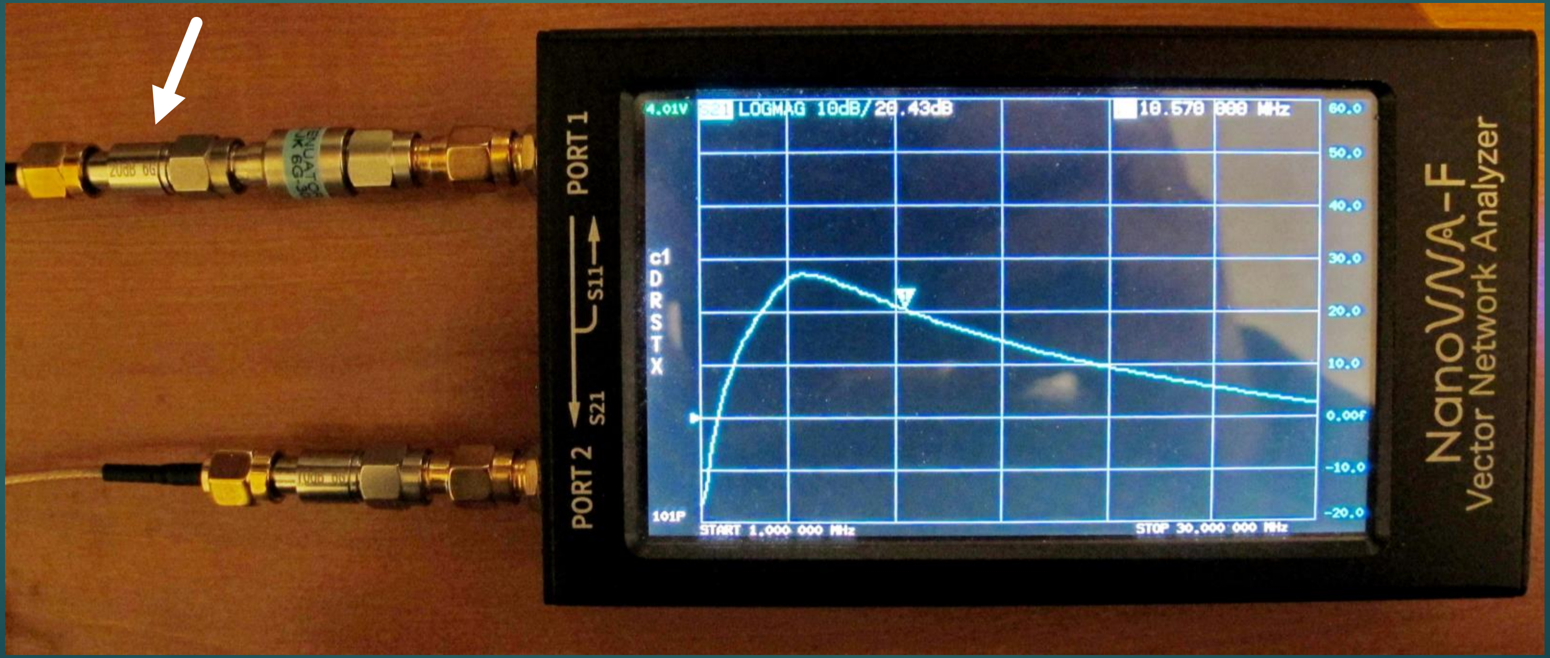


- 30 dB and 10 dB attenuators on ports 1 and 2 respectively
- Calibrated with these in place
- R5 bypassed for testing (due to 50 Ohm Rin of VNA)
- 32 dB gain at 10.7 MHz (low due to limiting)



Testing (2nd Stage Only)

- Added extra 20 dB attenuator to port 1, but did NOT recalibrate
- So, displayed gain is 20 dB lower than actual
- No gain compression this time ☺
- **40 dB gain at 10.7 MHz. 46 dB at 6 MHz**
- Needs some tweaking, and/or addition of first IF amp stage …



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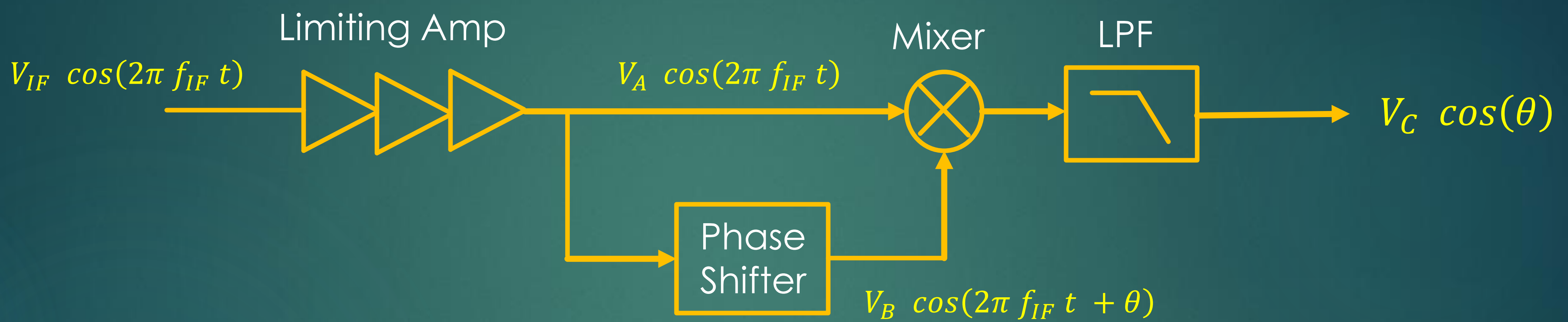
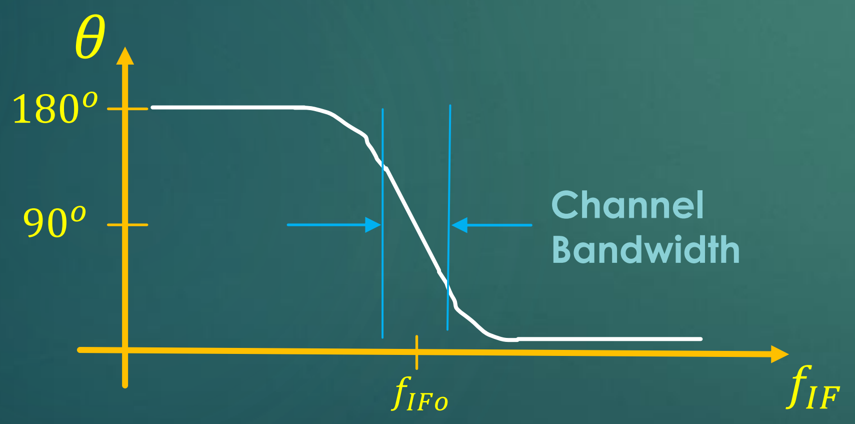
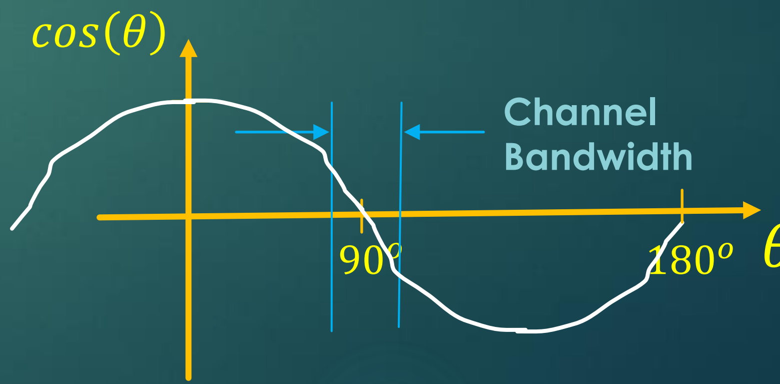
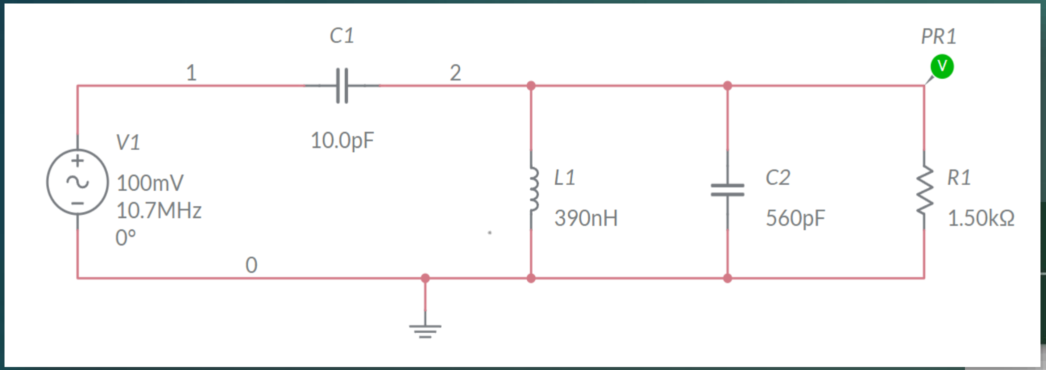
Classic FM Quadrature Subsystem

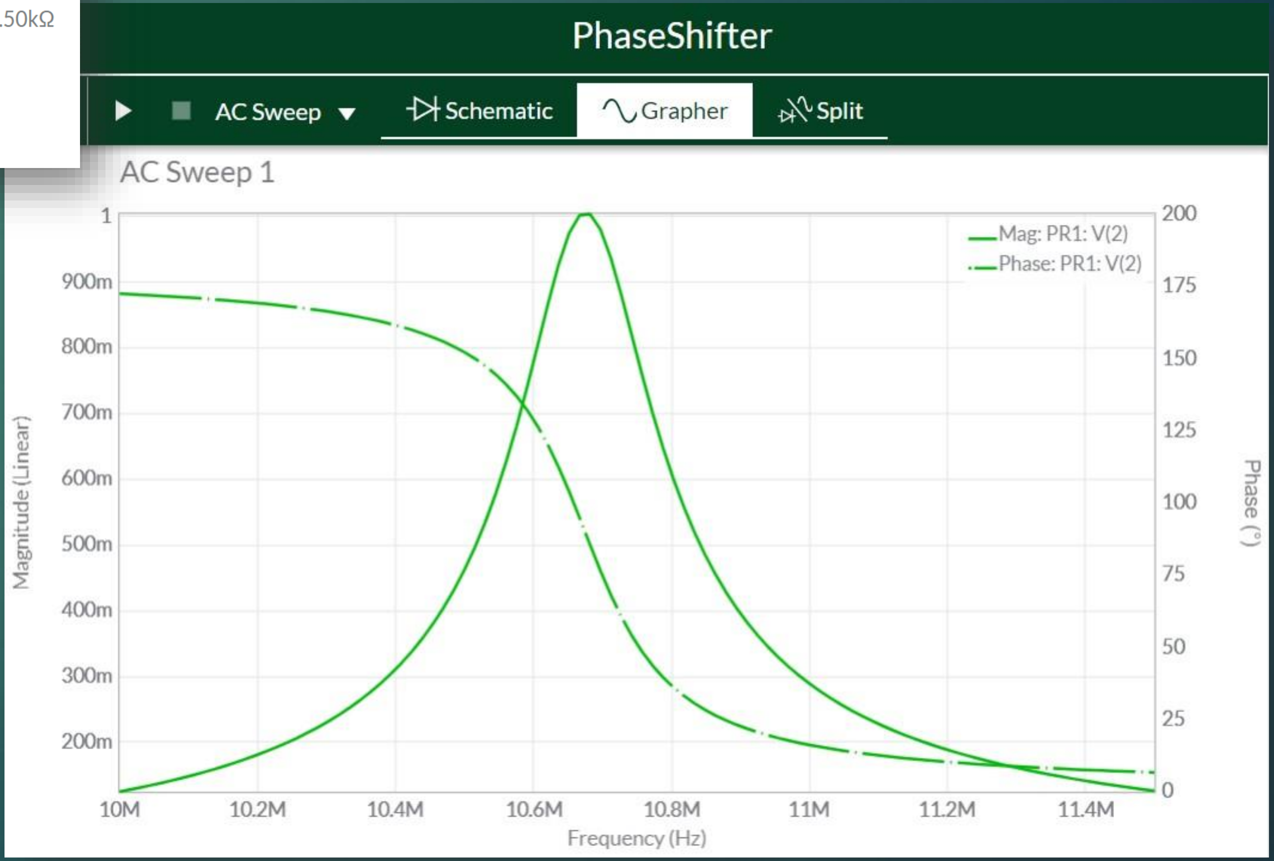






Phase Shifter Network

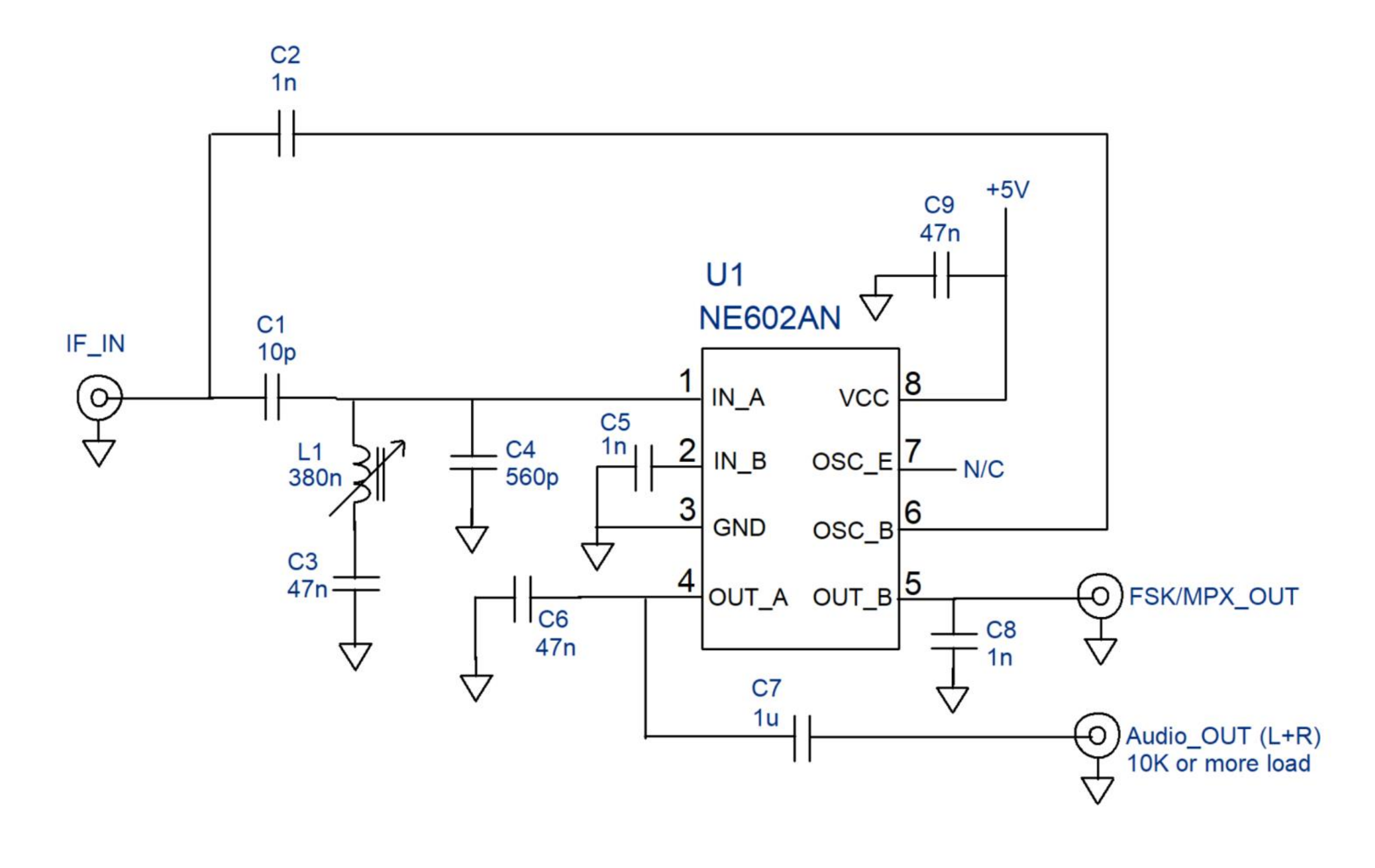




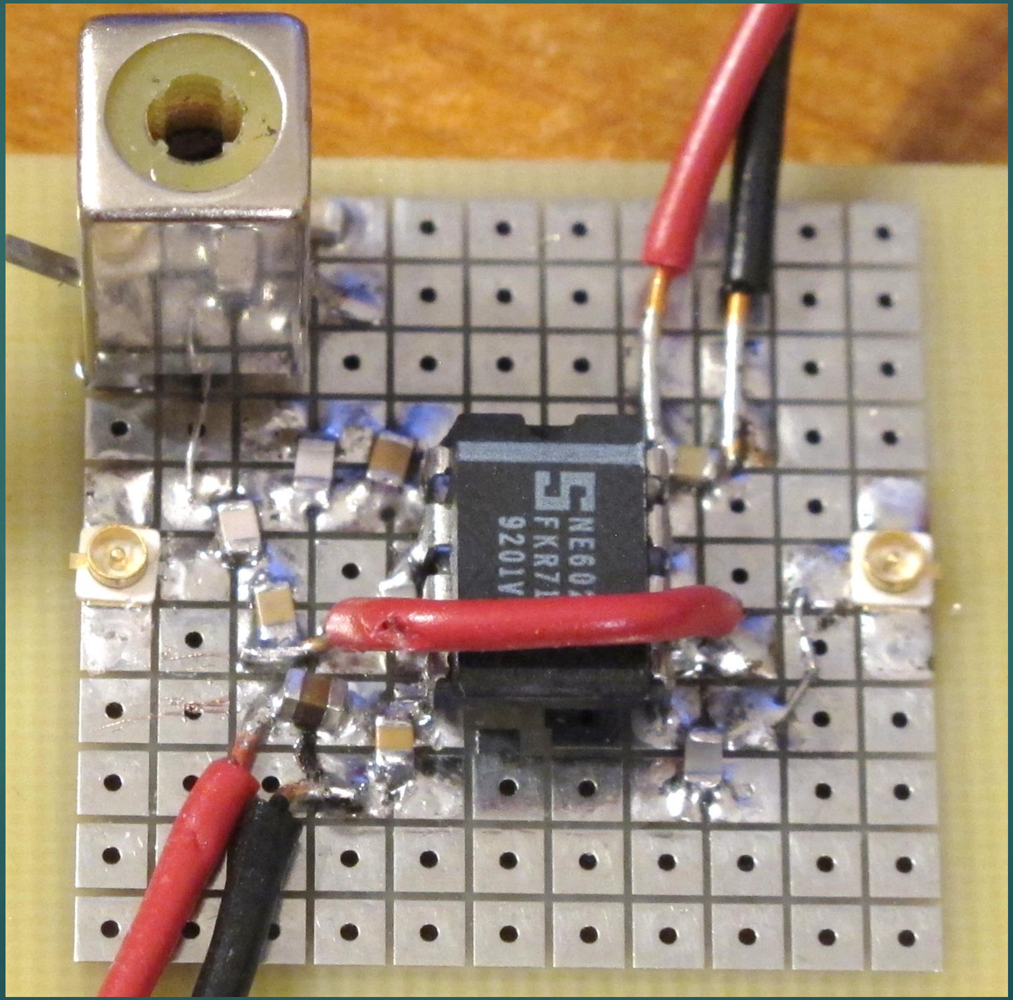
Analysis / Design:

- Use Norton equivalent for V1, C1 to understand behavior vs frequency
- Consider Q of L1 when making real-world circuits
- R1 is input R of mixer (together with parallel-form parasitic R of L1 and any physical resistor used)
- Q is high, so requires good quality inductor and alignment after build

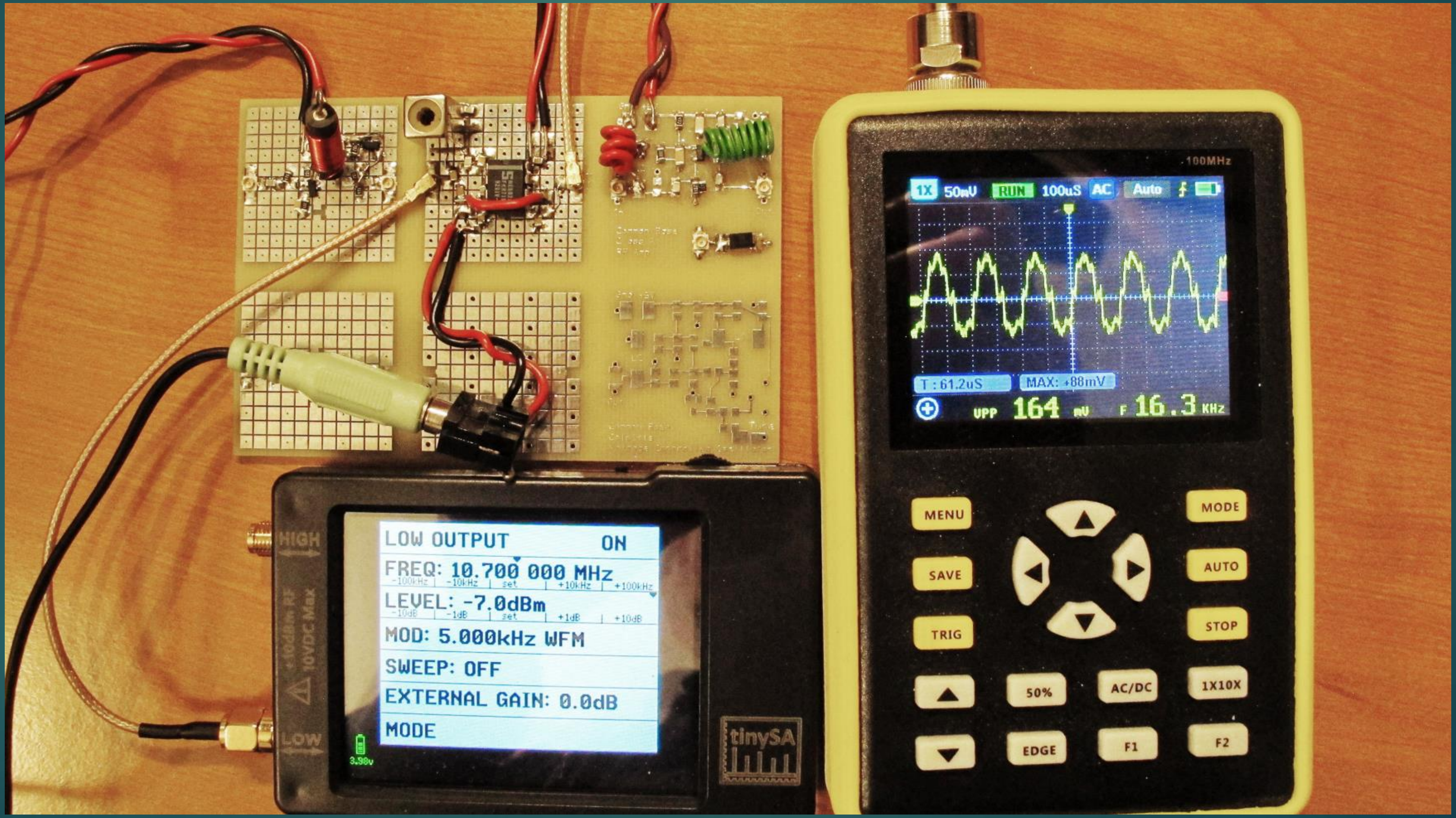
Demod Schematic Design



Construction



Testing


LOW OUTPUT ON
FREQ: 10.700 000 MHz
LEVEL: -7.0dBm
MOD: 5.000kHz WFM
SWEEP: OFF
EXTERNAL GAIN: 0.0dB
MODE
HIGH
LOW
tinySA
100MHz
1X 50mV RUN 100uS AC Auto
T : 61.2uS
MAX: +88mV
VPP 164 mV F 16.3 KHz
MENU
SAVE
TRIG
MODE
AUTO
STOP
50%
AC/DC
1X10X
EDGE
F1
F2

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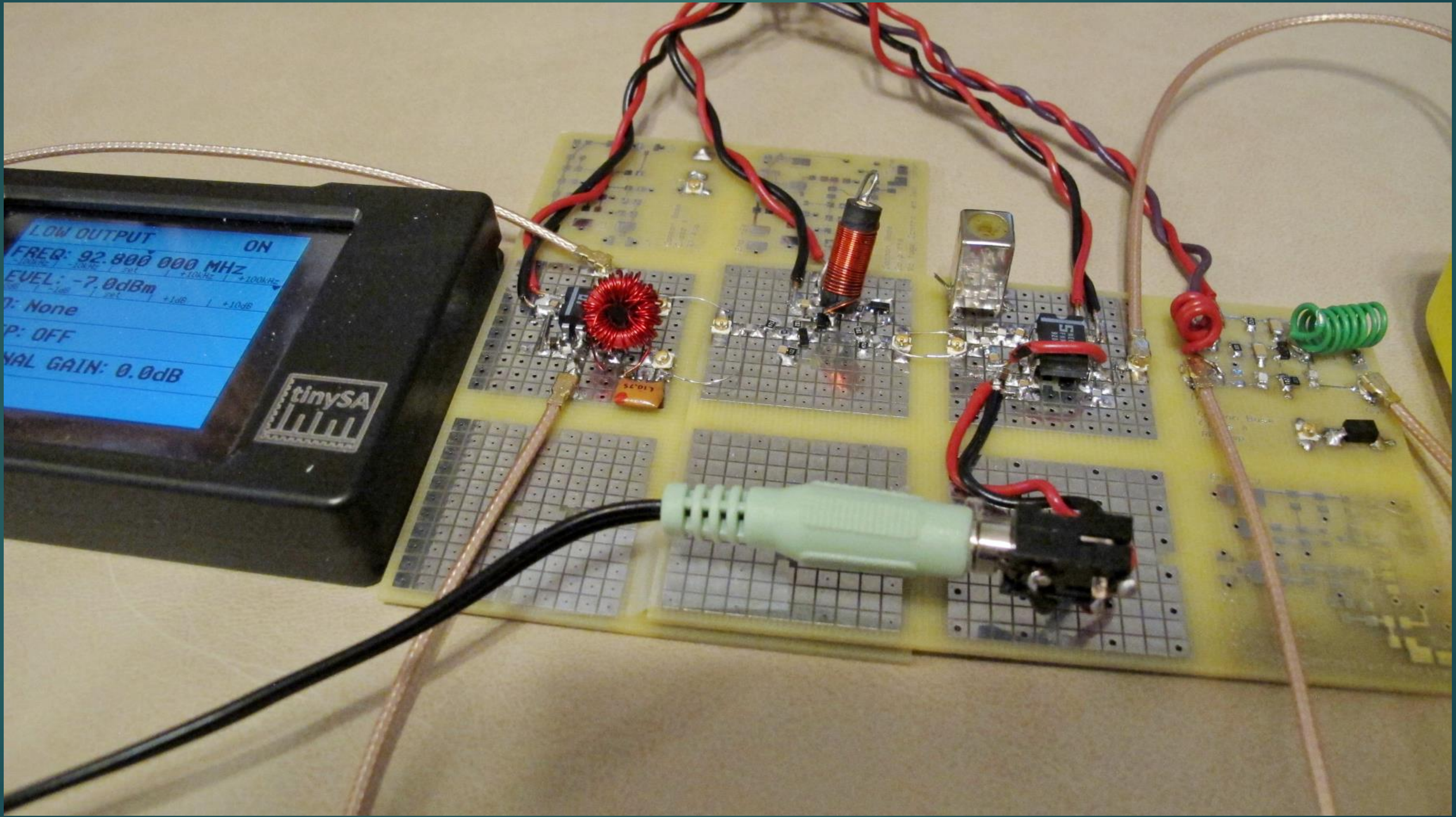
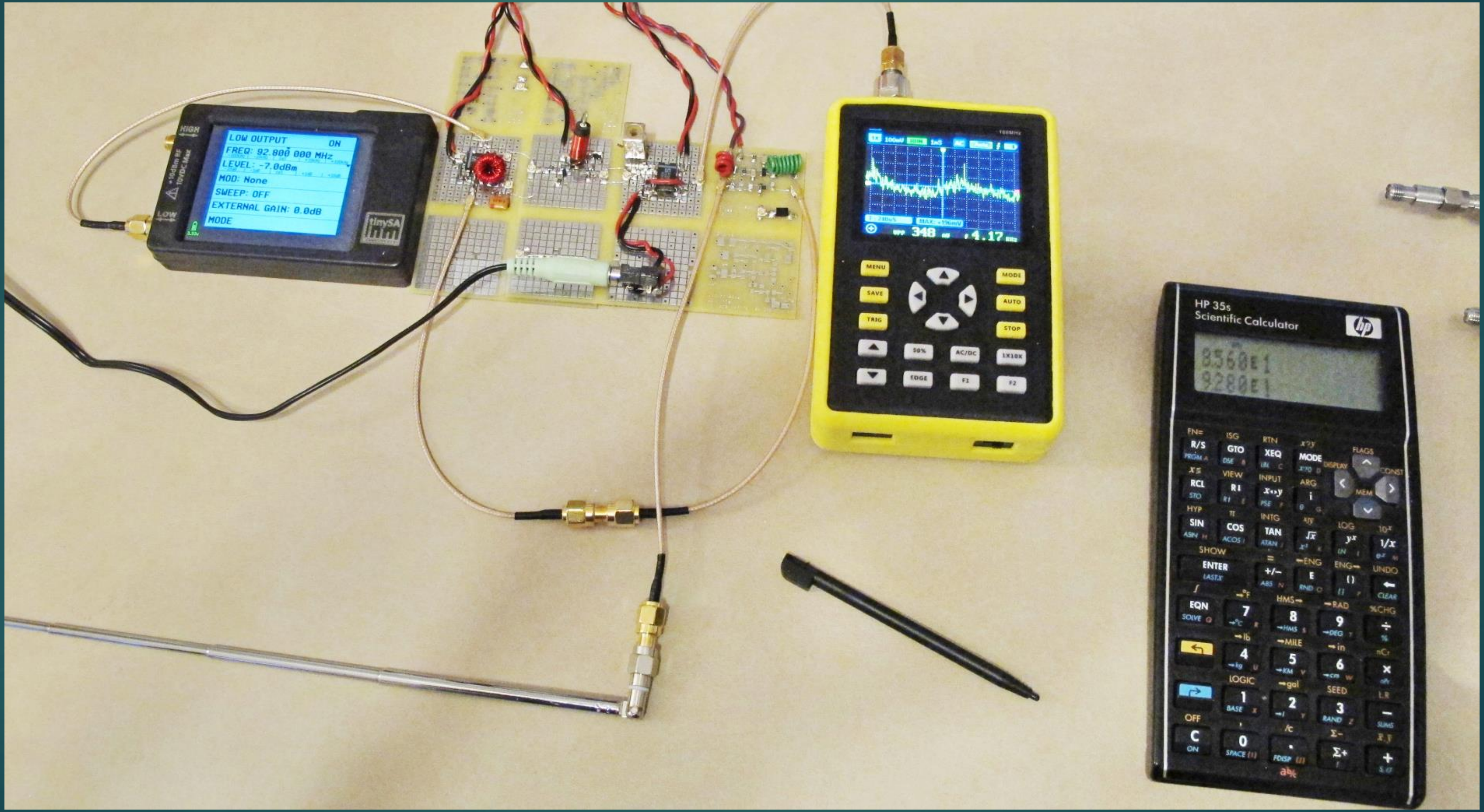
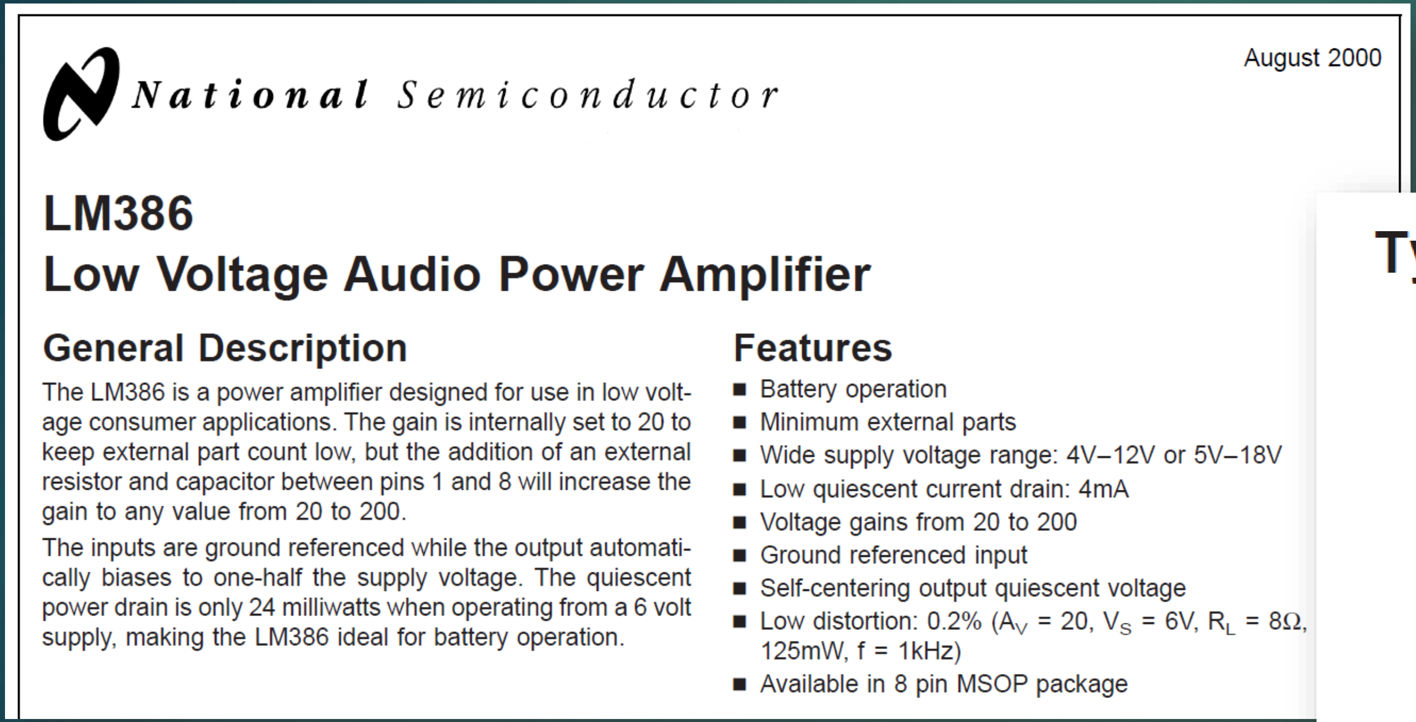
Final Assembly



First Sound


LOW OUTPUT ON
FREQ: 92.800 000 MHz
LEVEL: -7.0dBm
MOD: None
SWEEP: OFF
EXTERNAL GAIN: 0.0dB
MODE
tinySA
HIGH
LOW
MENU
SAVE
TRIG
MODE
AUTO
STOP
50%
AC/DC
1X10X
EDGE
F1
F2
HP 35s
Scientific Calculator

Optional Audio Amp



National Semiconductor

August 2000

LM386
Low Voltage Audio Power Amplifier

General Description

The LM386 is a power amplifier designed for use in low voltage consumer applications. The gain is internally set to 20 to keep external part count low, but the addition of an external resistor and capacitor between pins 1 and 8 will increase the gain to any value from 20 to 200.

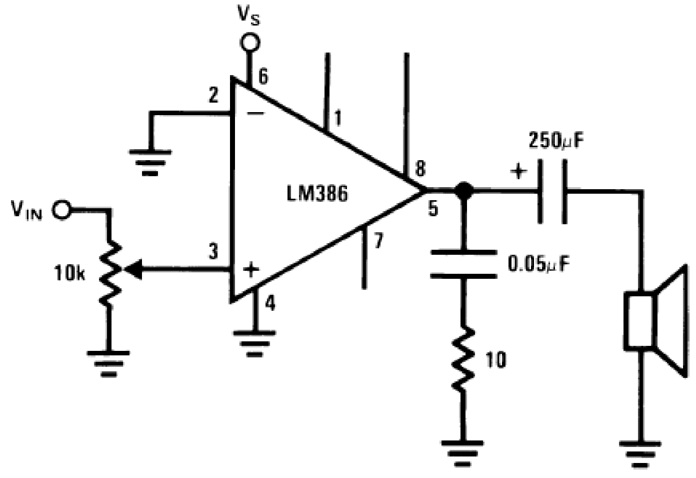
The inputs are ground referenced while the output automatically biases to one-half the supply voltage. The quiescent power drain is only 24 milliwatts when operating from a 6 volt supply, making the LM386 ideal for battery operation.

Features

- Battery operation
- Minimum external parts
- Wide supply voltage range: 4V–12V or 5V–18V
- Low quiescent current drain: 4mA
- Voltage gains from 20 to 200
- Ground referenced input
- Self-centering output quiescent voltage
- Low distortion: 0.2% (A_V = 20, V_S = 6V, R_L = 8Ω, 125mW, f = 1kHz)
- Available in 8 pin MSOP package

Typical Applications

Amplifier with Gain = 20
Minimum Parts



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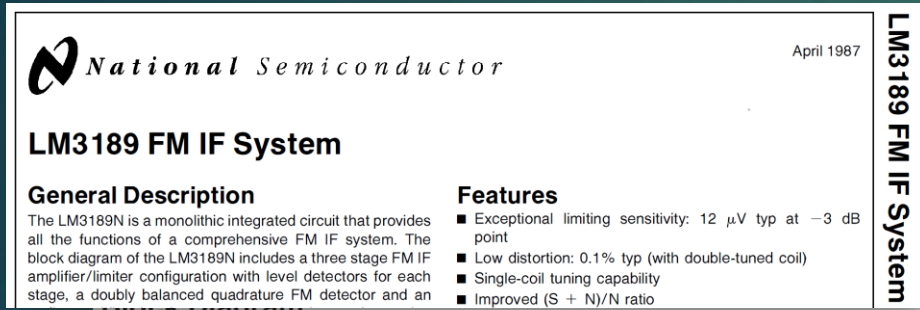
Other Options for FM IF Subsystem



National Semiconductor

April 1987

LM3189 FM IF System

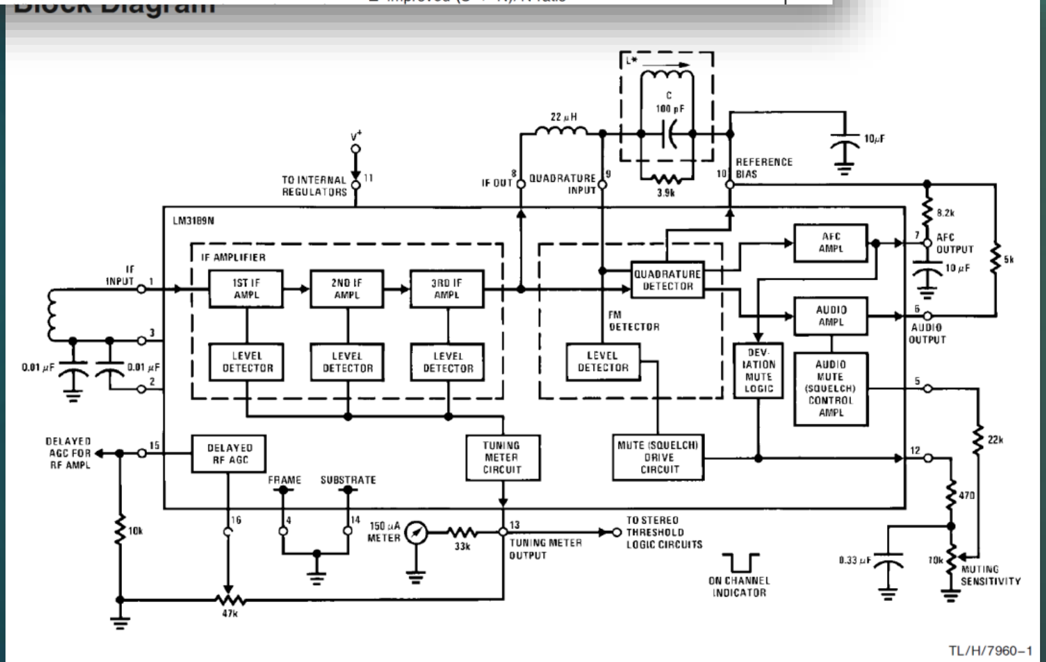
LM3189 FM IF System

General Description

The LM3189N is a monolithic integrated circuit that provides all the functions of a comprehensive FM IF system. The block diagram of the LM3189N includes a three stage FM IF amplifier/limiter configuration with level detectors for each stage, a doubly balanced quadrature FM detector and an

Features

- Exceptional limiting sensitivity: 12 μV typ at −3 dB point
- Low distortion: 0.1% typ (with double-tuned coil)
- Single-coil tuning capability
- Improved (S + N)/N ratio



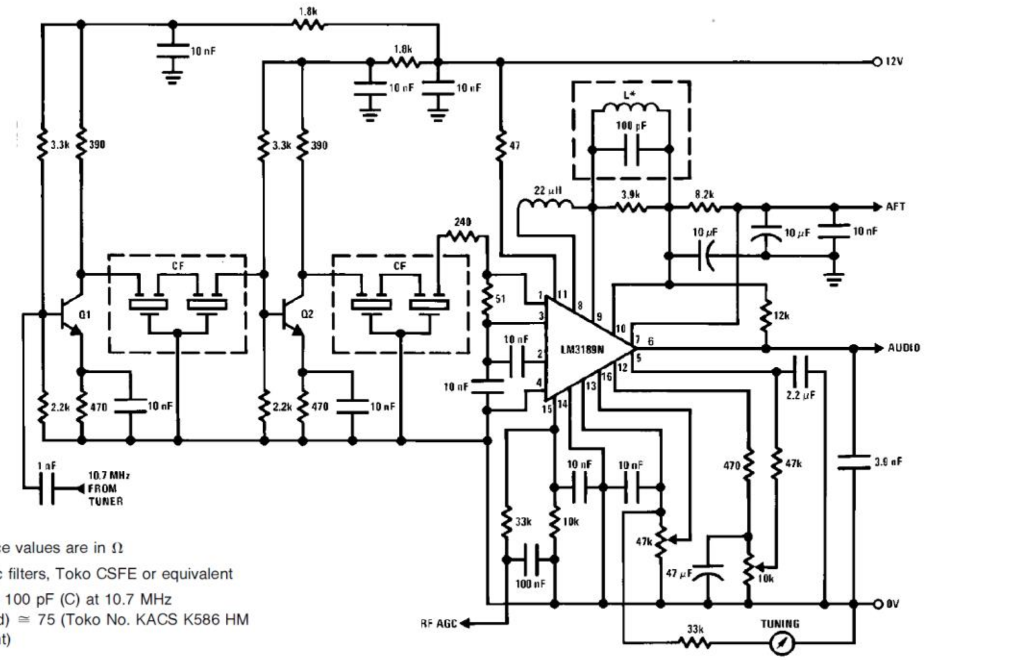
All resistance values are in Ω

*L tunes with 100 pF (C) at 10.7 MHz, $Q_0 \simeq 75$
(Toko No. KACS K586HM or equivalent)

Complete FM IF System for High Quality Tuners

The circuit provides a complete FM IF system for a high quality receiver. Either one or two stages of amplification and bandpass filtering may be desired, depening on the receiver requirements. See graph for Typical Limiting and Noise Characteristics for each circuit configuration which can be compared to the LM3189N alone.

Complete FM IF System for High Quality Receivers



All resistance values are in Ω

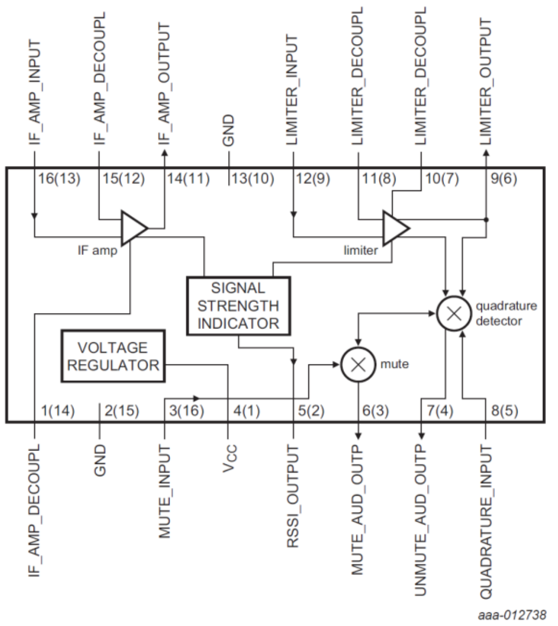
CF: Ceramic filters, Toko CSFE or equivalent

*L tunes with 100 pF (C) at 10.7 MHz
Q_O(unloaded) ≃ 75 (Toko No. KACS K586 HM or equivalent)

TL/H/7960–5

Other Options for FM IF Subsystem

5. Block diagram



Pin numbers for SO16; HXQFN16 pins shown in parentheses

Fig 1. Block diagram of SA604A

NXP Semiconductors
SA604A
High-performance low-power FM IF system

13. Application information

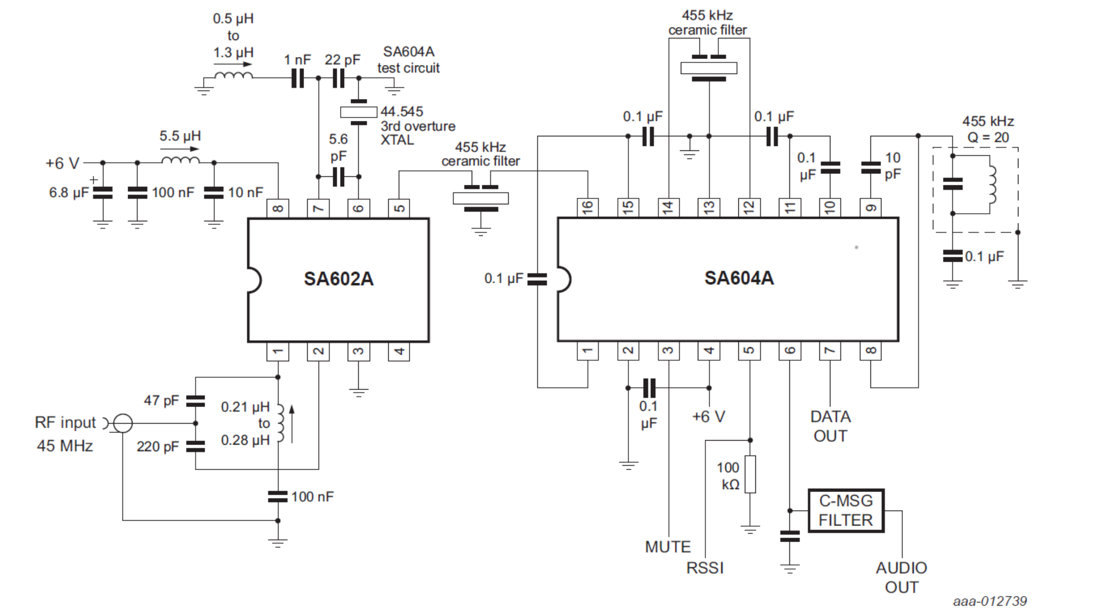


Fig 6. Typical application cellular radio (45 MHz RF input and 455 kHz IF)

Full Receivers on a Chip

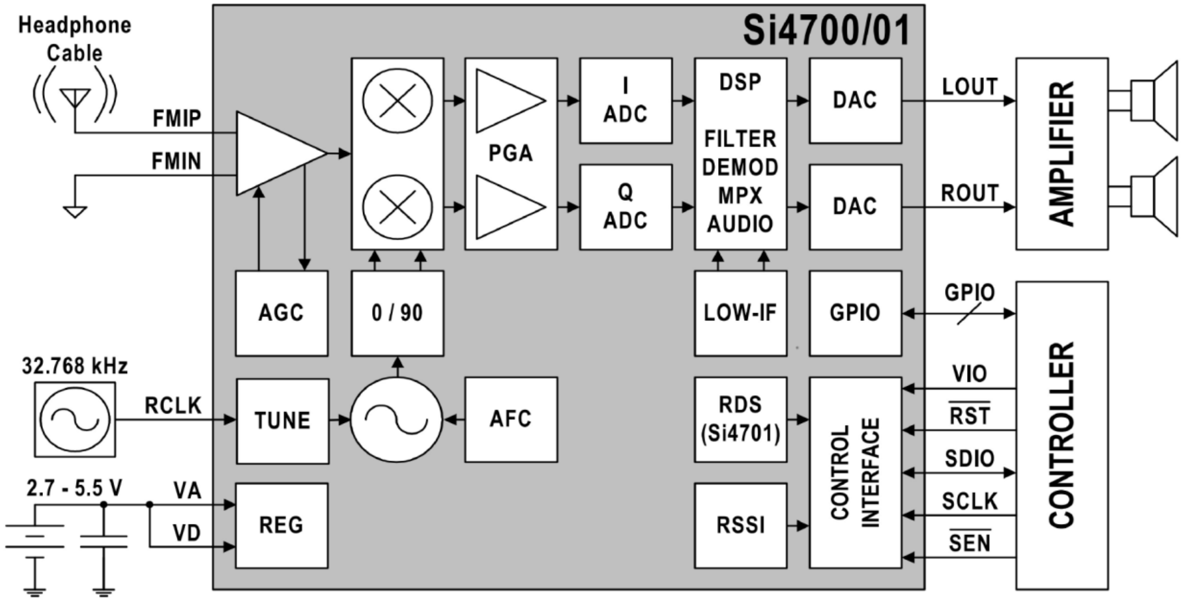
SILICON LABORATORIES

Si4700/01

Broadcast FM Radio Tuner for Portable Applications

Description

The Si4700 is the industry's first FM radio tuner IC to leverage digital integration and 100% CMOS process technology, resulting in a completely integrated solution that requires only one external supply bypass capacitor and less than 20 mm^2 of board space. Offering unmatched integration, the Si4700 allows FM radio reception to be added to a variety of portable devices where board space, performance, low power consumption, and ease of use are essential.



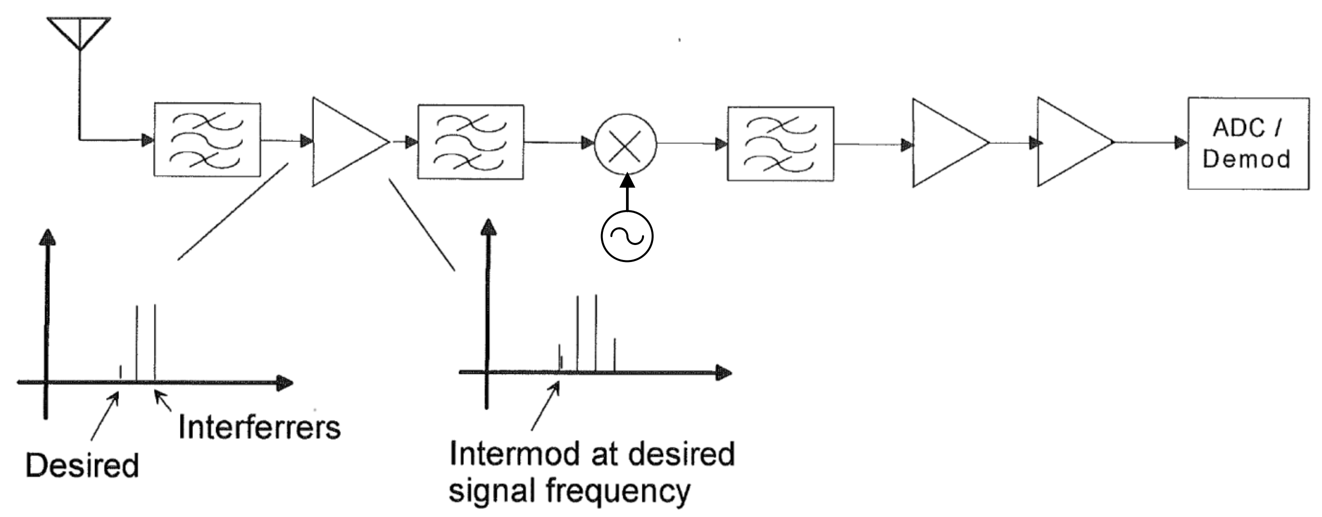
Performance Issues

(possible future videos)

- Selectivity and Image Rejection
- Weak Signal Performance
- Strong Signal Performance
- Dynamic Range and Power Consumption

Preview

The Intermod Problem



Can occur in any circuits up to last IF filter.
Typically occurs at lower power than blocking problems.
Can be mitigated with good preselect filters if interferrers are out-of-band
Cannot be filtered if interferrers are close to desired signal frequency .
Requires higher power LNA, mixer, etc.

Thanks For Watching !