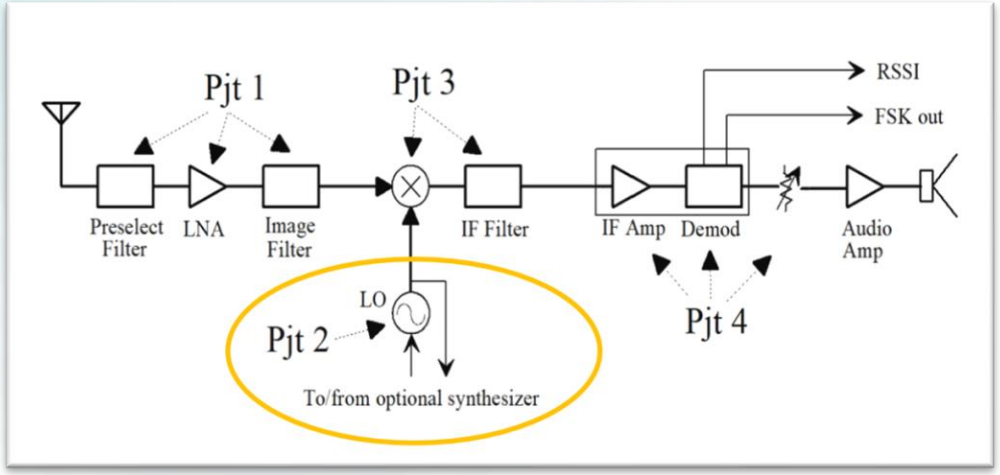
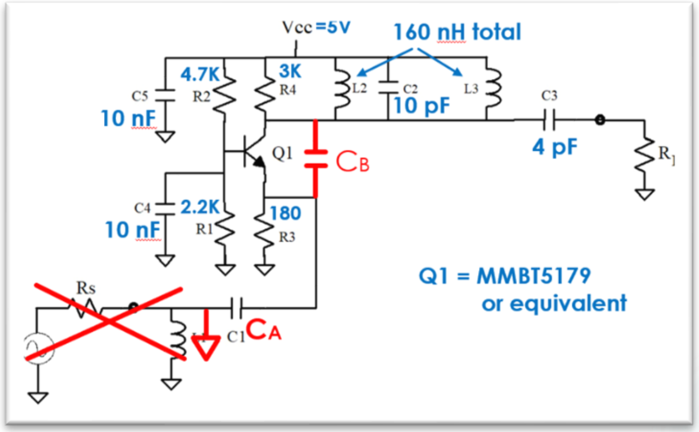
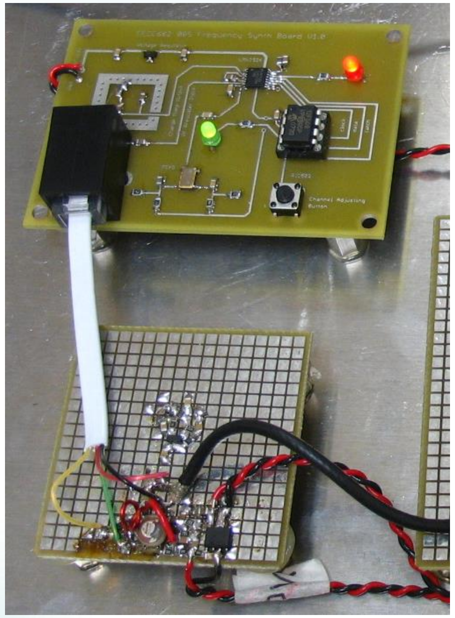
Radio Design 101
Episode 4 – RF Oscillators

Slides downloaded from: https://ecefiles.org/rf-design/
Companion video at: https://www.youtube.com/watch?v=oJQONLdFC20

This episode covers radio frequency oscillator circuits, ranging from discrete designs through modern integrated circuit architectures. Associated topics include oscillator types (Hartley vs Colpitts), tuning using varactor diodes, and achieving frequency stability using crystals and PLL frequency synthesizers.



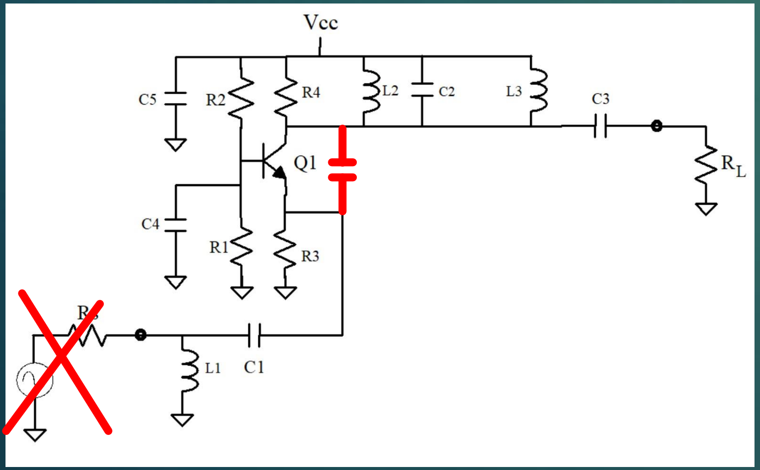


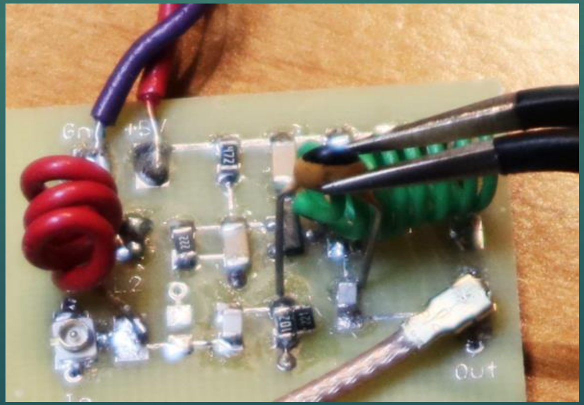


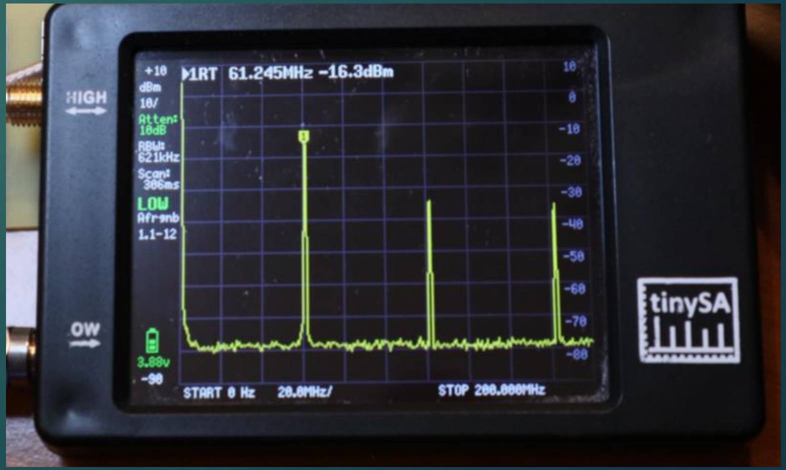
Radio Design 101

Episode 4

RF Oscillators

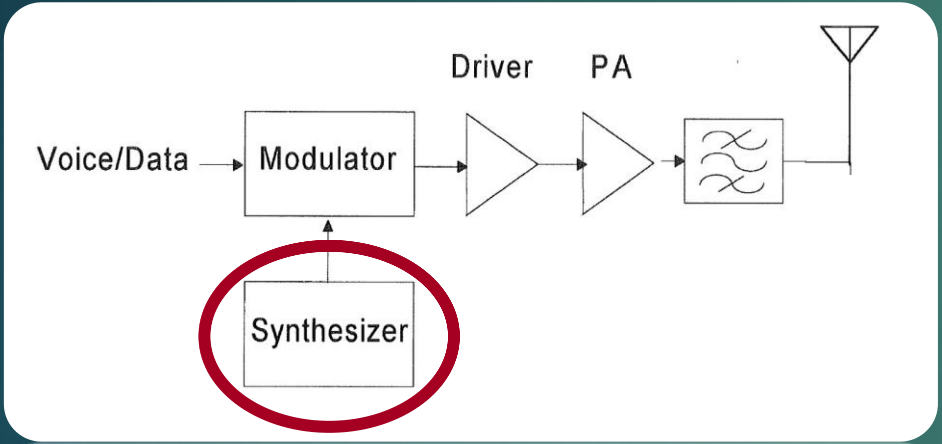




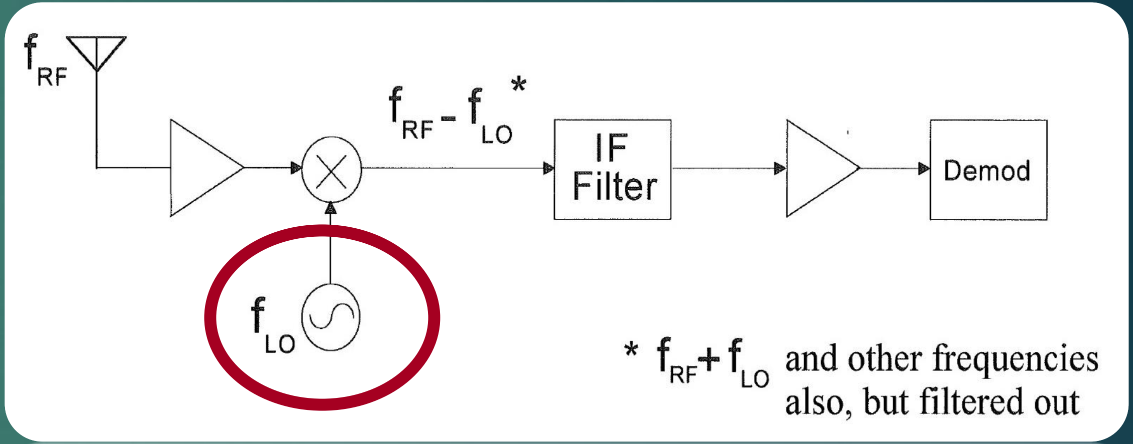


System Context

Frequency Synthesized Transmitter*

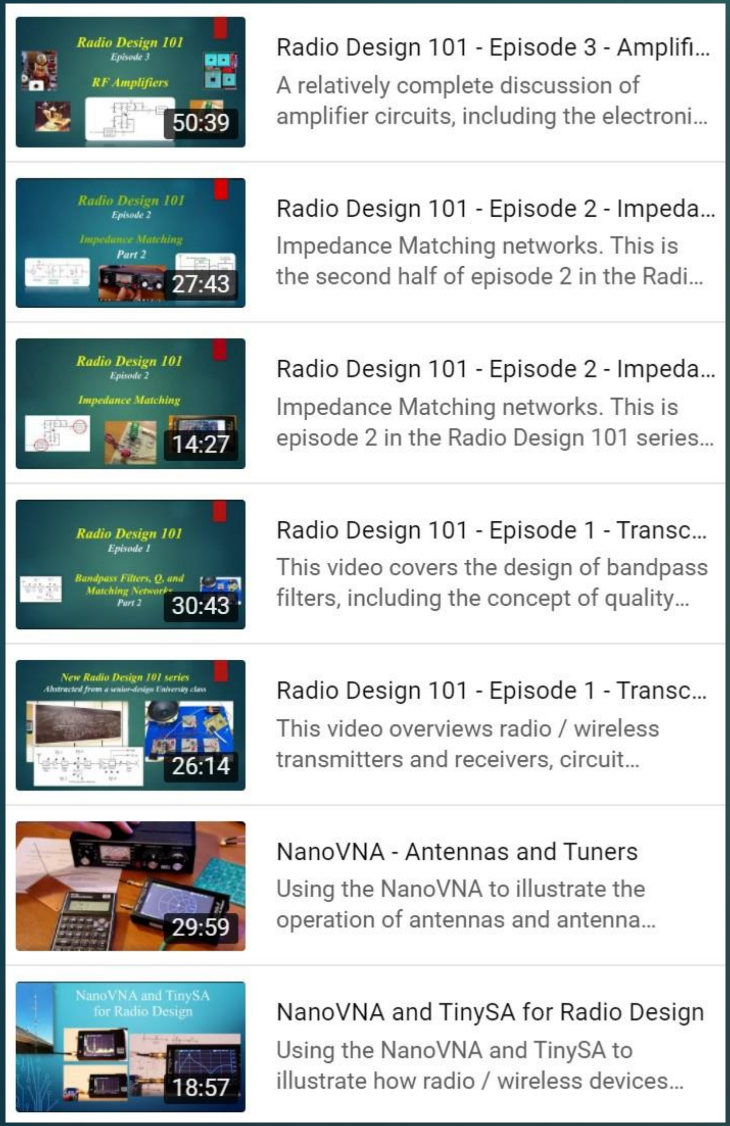


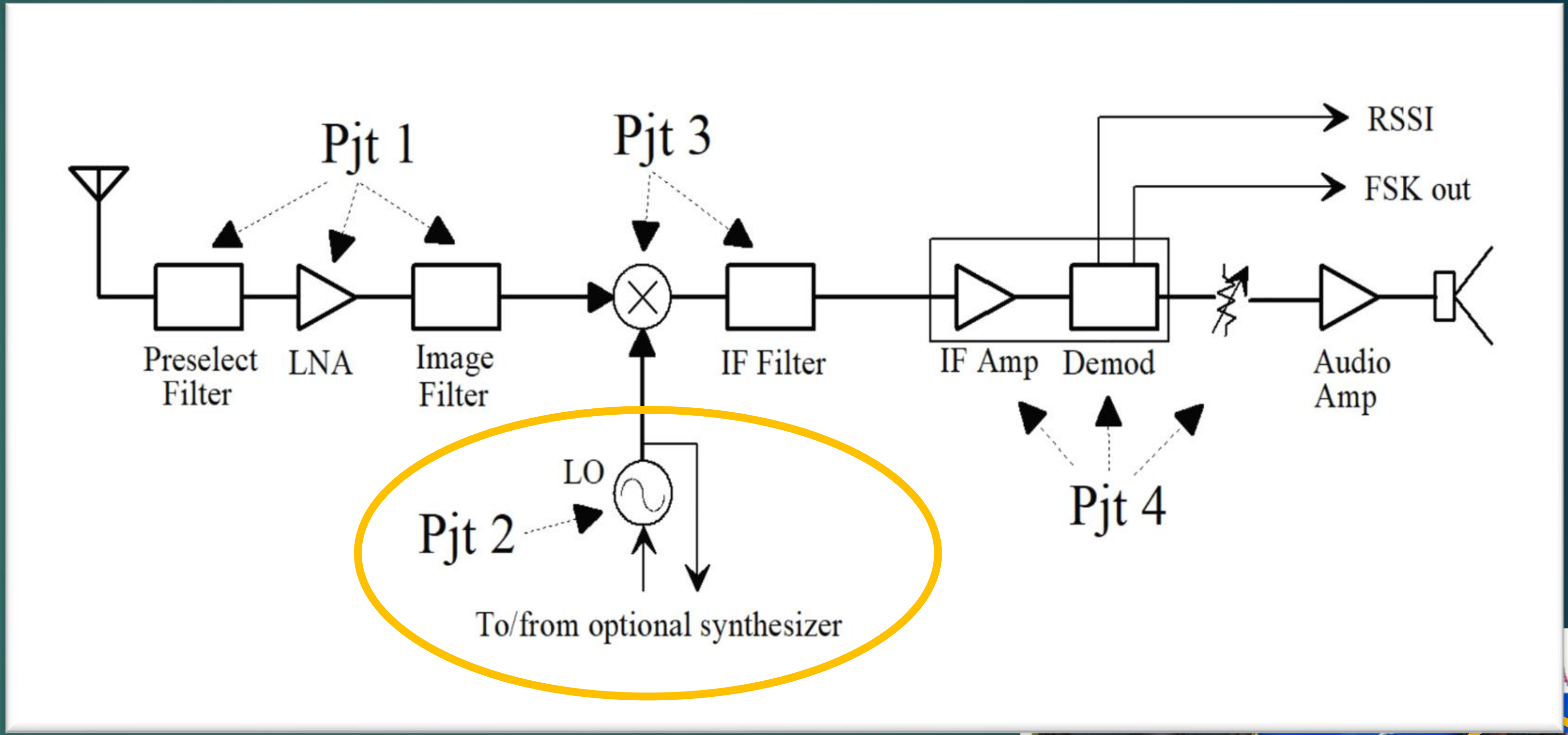
Superheterodyne Receiver



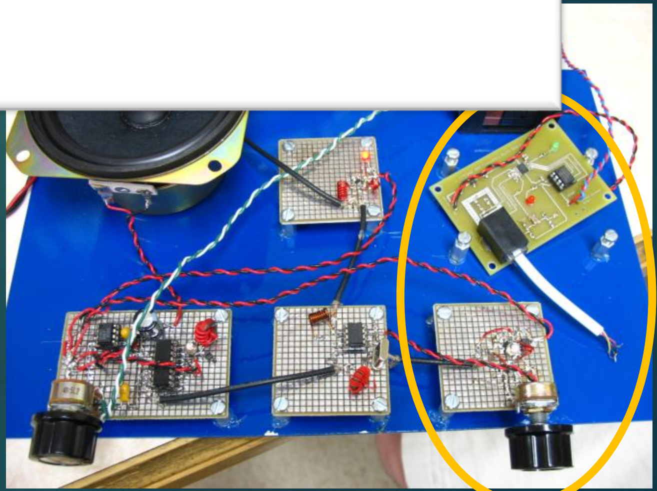
***WARNING:** Transmitting requires license and proper frequency control

Radio Design 101 "Semester Projects"



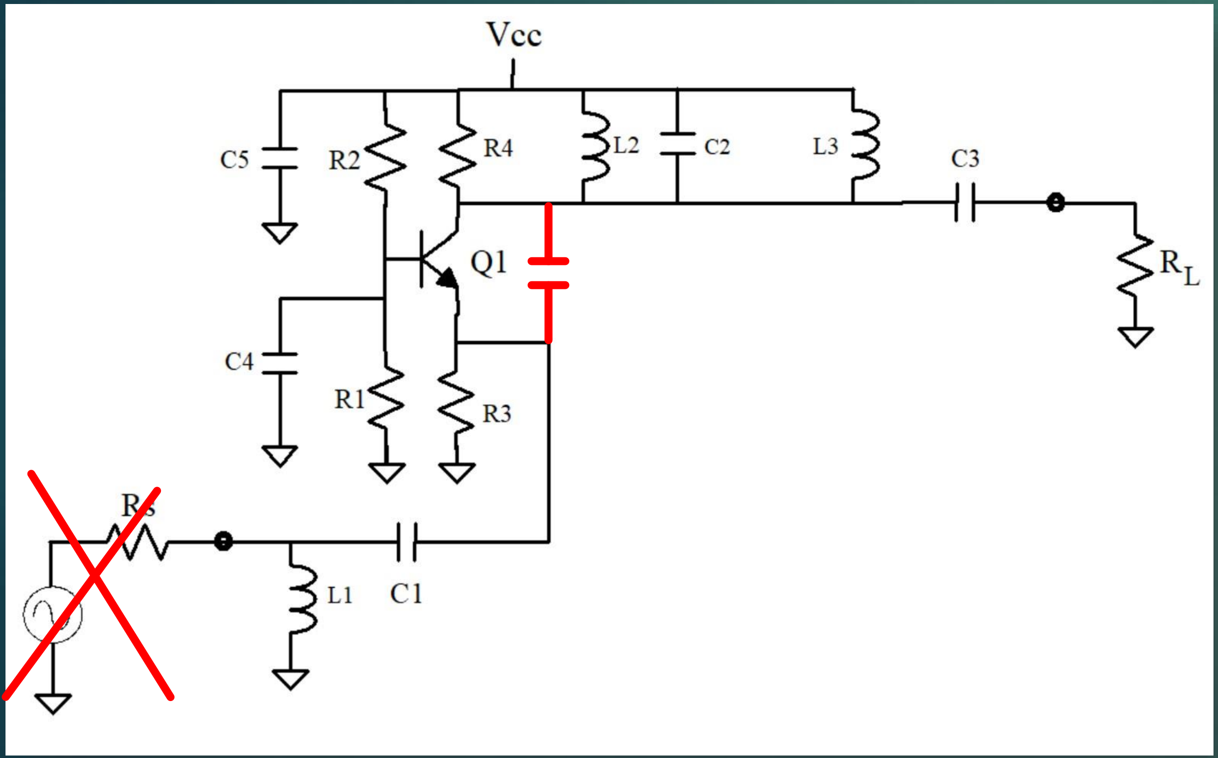


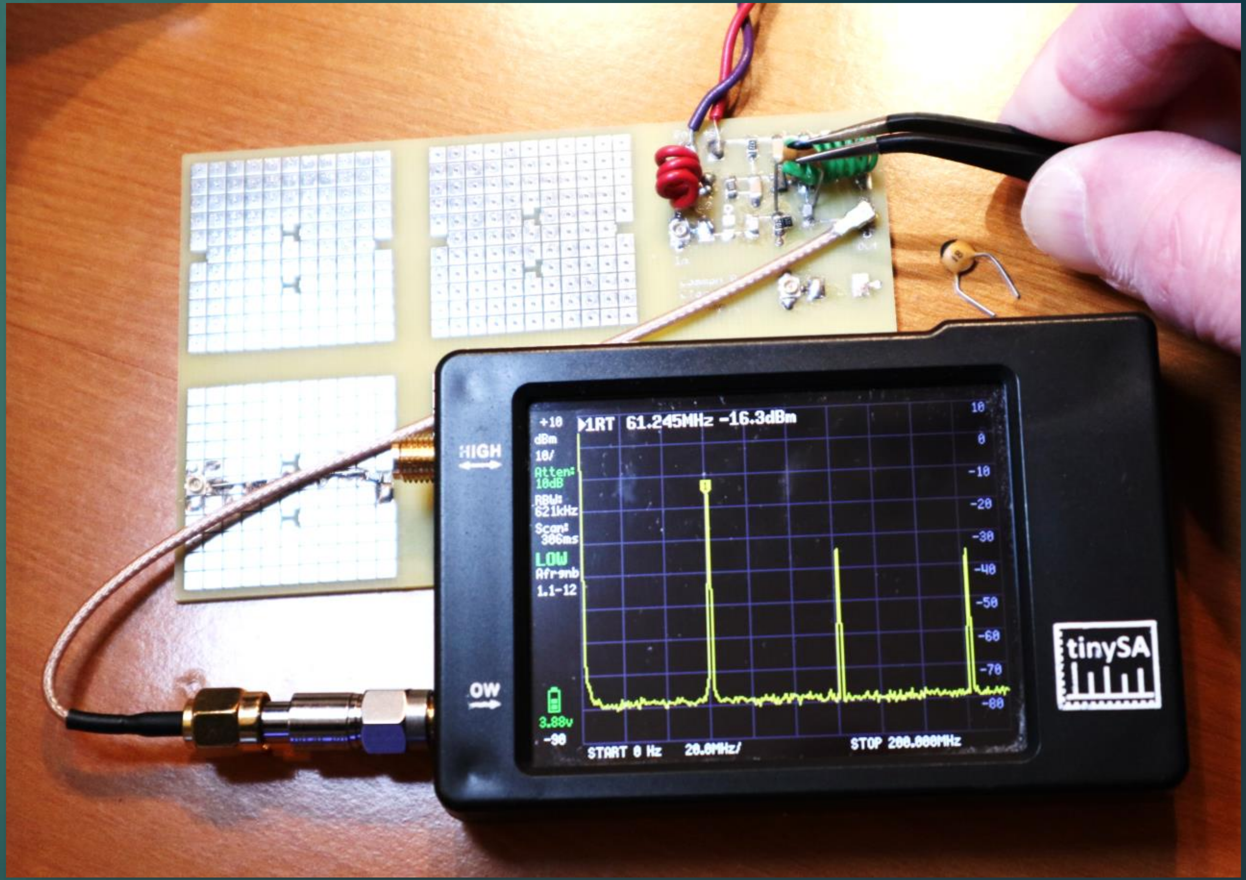
Project 2 – Local Oscillator
(This Video)



Overview

Amplifier + <u>(Positive) Feedback</u> = Oscillator





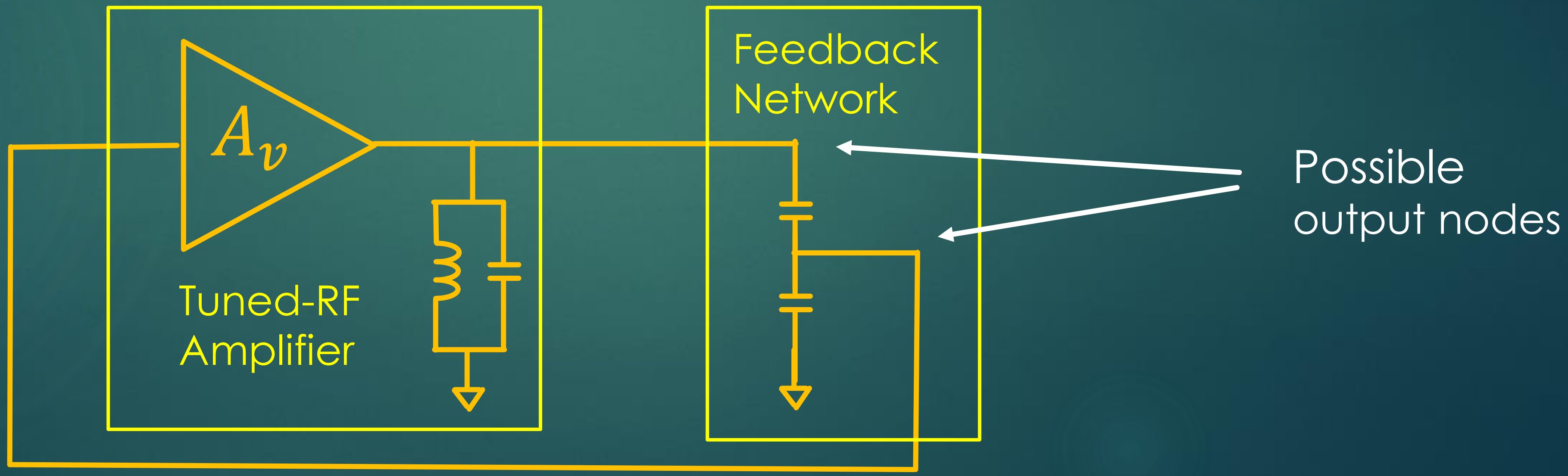
Topic Outline

- ***LC Oscillator Basics***
- ***Hartley and Colpitts circuits***
- ***Voltage Controlled Oscillators***
- ***Crystal Oscillators and Synthesizers***

How to Make an LC Oscillator

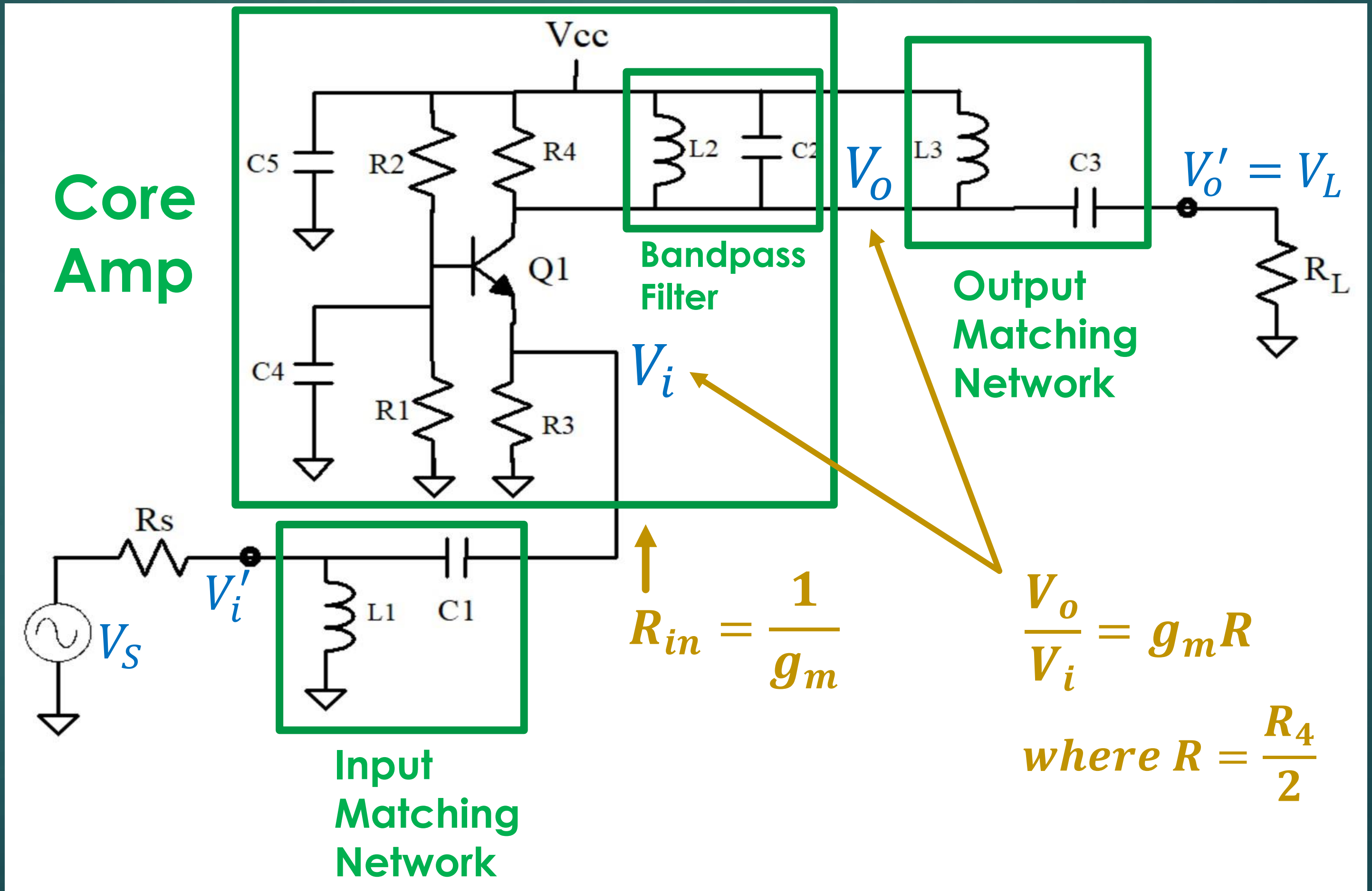
- Design a tuned-RF amplifier
- Add positive (in-phase) feedback
- Select output node and assess loading and inductor-Q effects on gain
- Verify “loop gain” is > 1 at center frequency

- See also: https://en.wikipedia.org/wiki/Barkhausen_stability_criterion



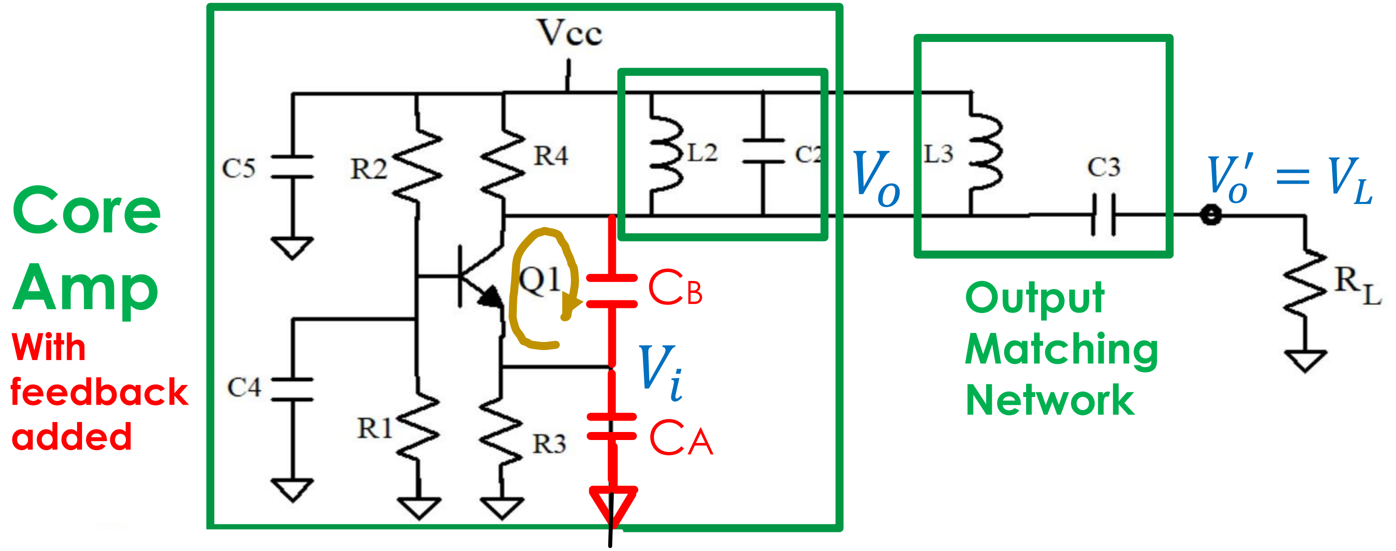
Leveraging our Existing Work

Recall our Common-Base amplifier from Episode 2:



Modify to Create Oscillation

- Delete input port and input matching network (and optionally R4)
- Add feedback network and adjust L2, C2 to get desired frequency



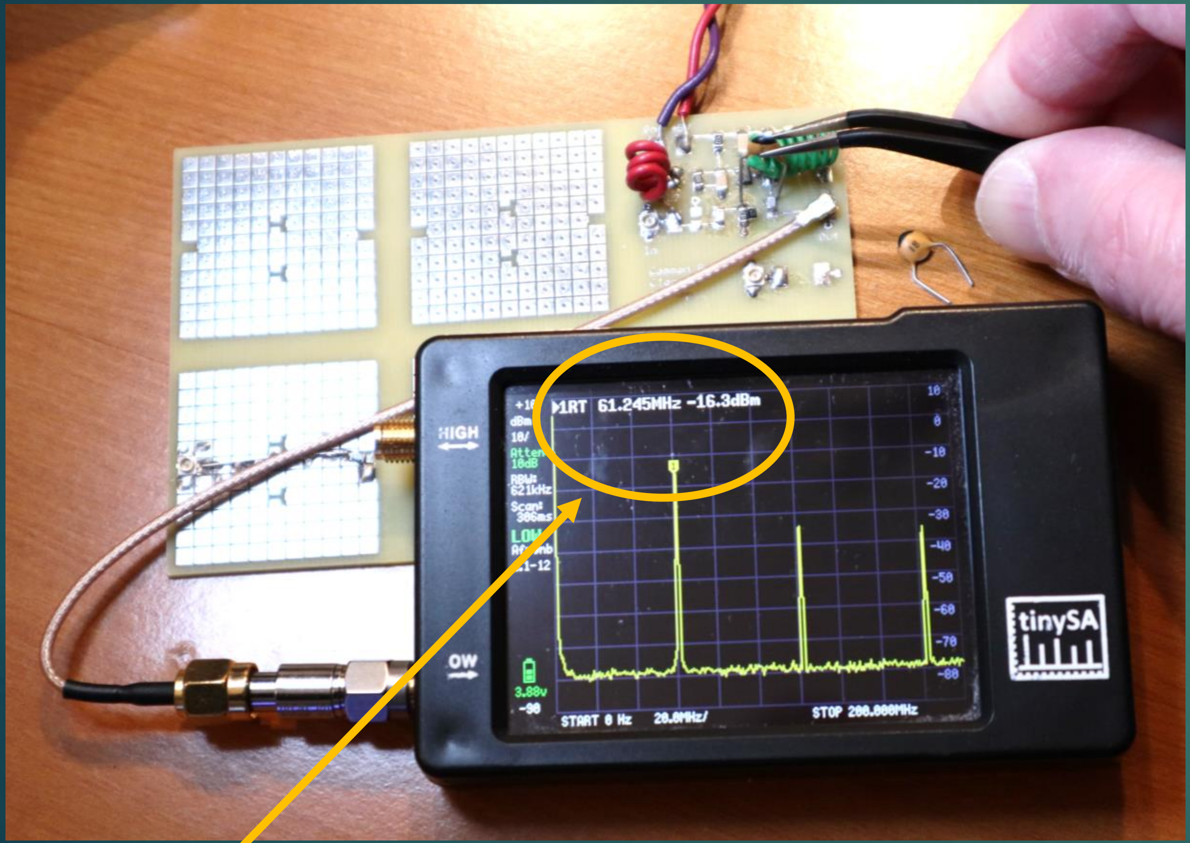
- Voltage divider CA, CB feeds output back to input
- Oscillates if "loop gain" from Vi to Vo and back to Vi
  Av-loop is > 1 and the reactance of CA is XCA < Rin
- Typically, CB = CA to CB = CA / 4 will make Av-loop > 1

NOTE:

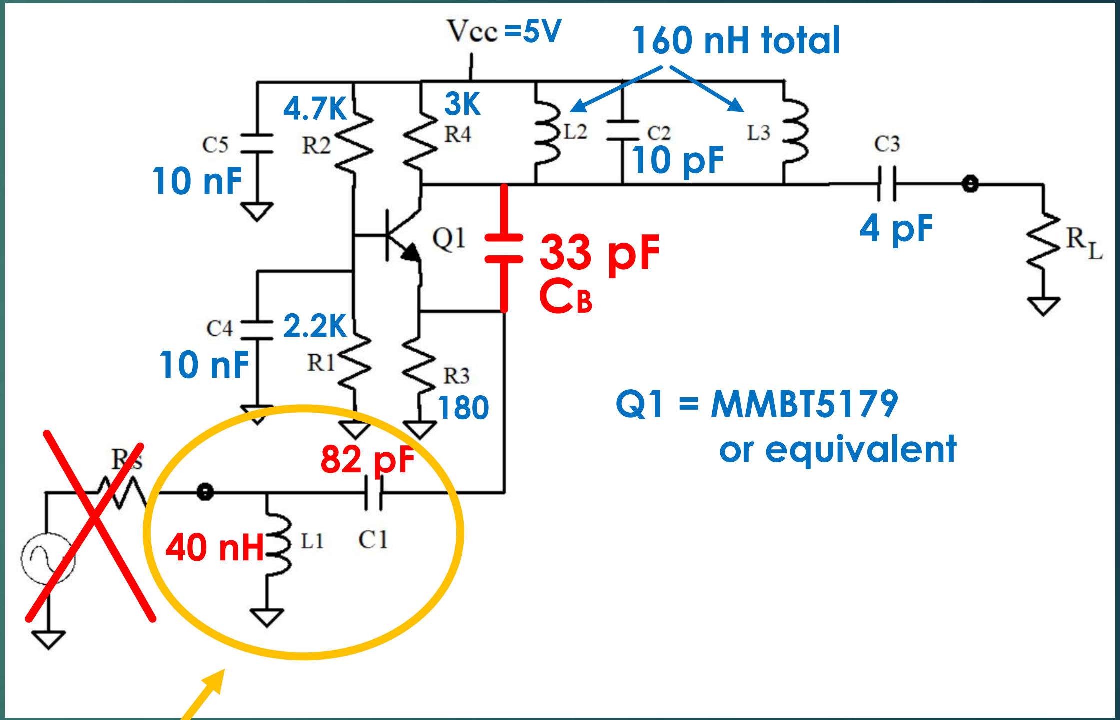
$If\ X_{C_A} \ll R_{in}\ then\ C_A\ C_B$

$is\ part\ of\ a\ tapped-capacitor$
$impedance\ matching\ network$
$that\ transforms\ R_{in}\ to\ R_{in}'$
$seen\ by\ the\ collector\ node.$

Why Did This Work Without C_A ?



fo = 61 MHz

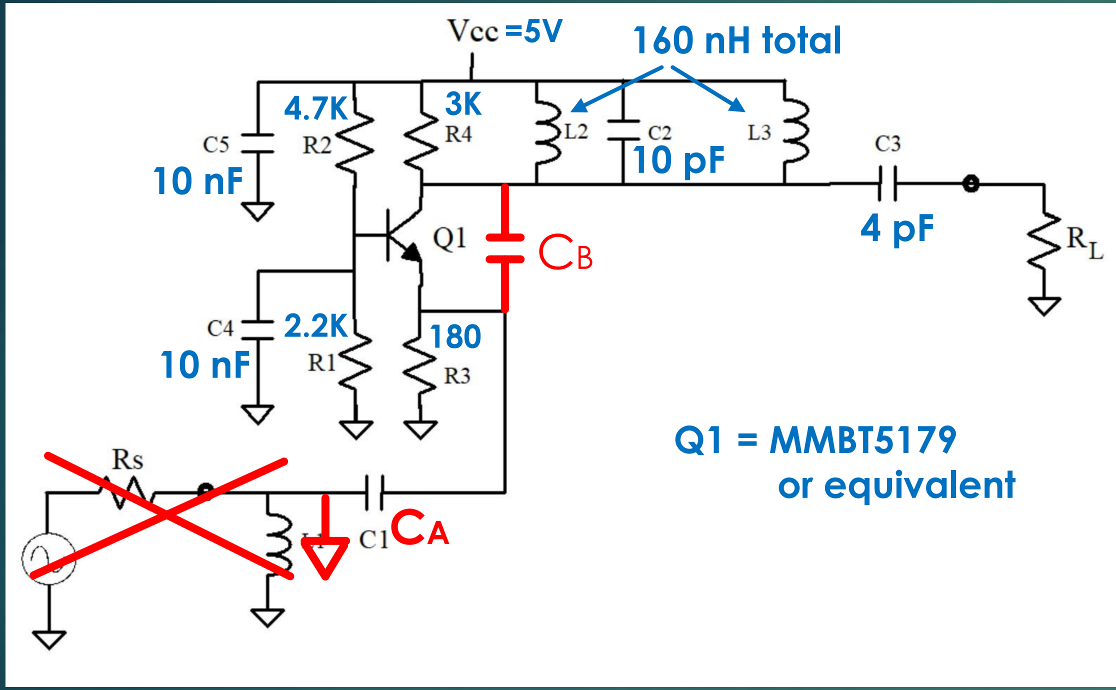


Looks like 160 pF at 61 MHz

(@ 61 MHz Z_{C1} = - j 31 and Z_{L1} = +j 15)

ALSO – Cbe inside Q1 is 15 pF @ Ic = 5mA

Project 2 "Homework" ☺



Redesign this for use in FM receiver

PROCEEDURE :

- Delete L1 and ground C1 (now labeled C_A)
- Increase R3 to 360 to raise R_{in} from 10 to 20 Ohms
- Find C_A to give X_{CA} = 20 at 87 MHz
- Find C_B as 1/3 of C_A
- Adjust L total to resonate at 87 MHz*
- Build and test
- Add varactor tuning to cover 77.2 to 97.2 MHz**
- Refine and retest

* Total C to ground at collector of Q1 is C2 + C3 + C_{bc} + (C_B - - C_A),
where C_{bc} collector-base C inside Q1 (about 1pF) and (C_B - - C_A) is the series combination of C_B and C_A

** To tune FM broadcast receiver with 10.7 MHz IF. See varactor diode discussion coming up

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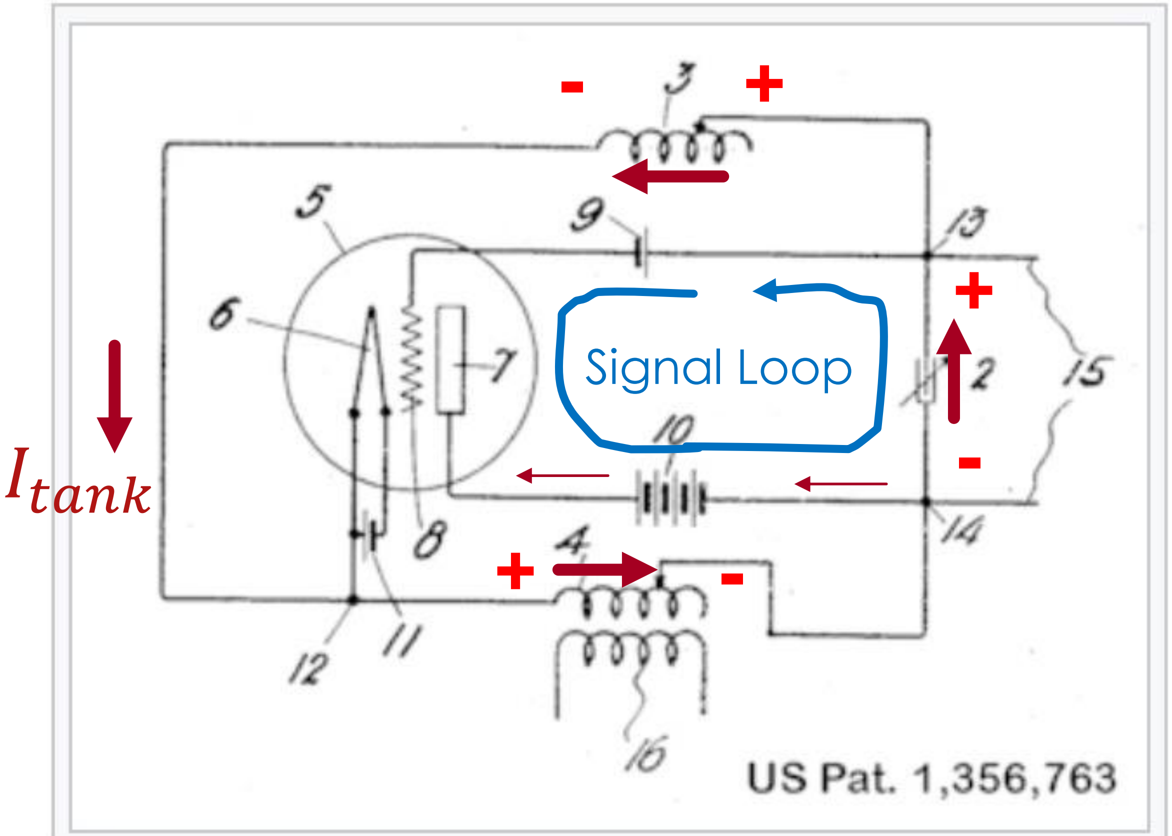
- *Crystal Oscillators and Synthesizers*

1915 Hartley Patent

https://en.wikipedia.org/wiki/Hartley_oscillator

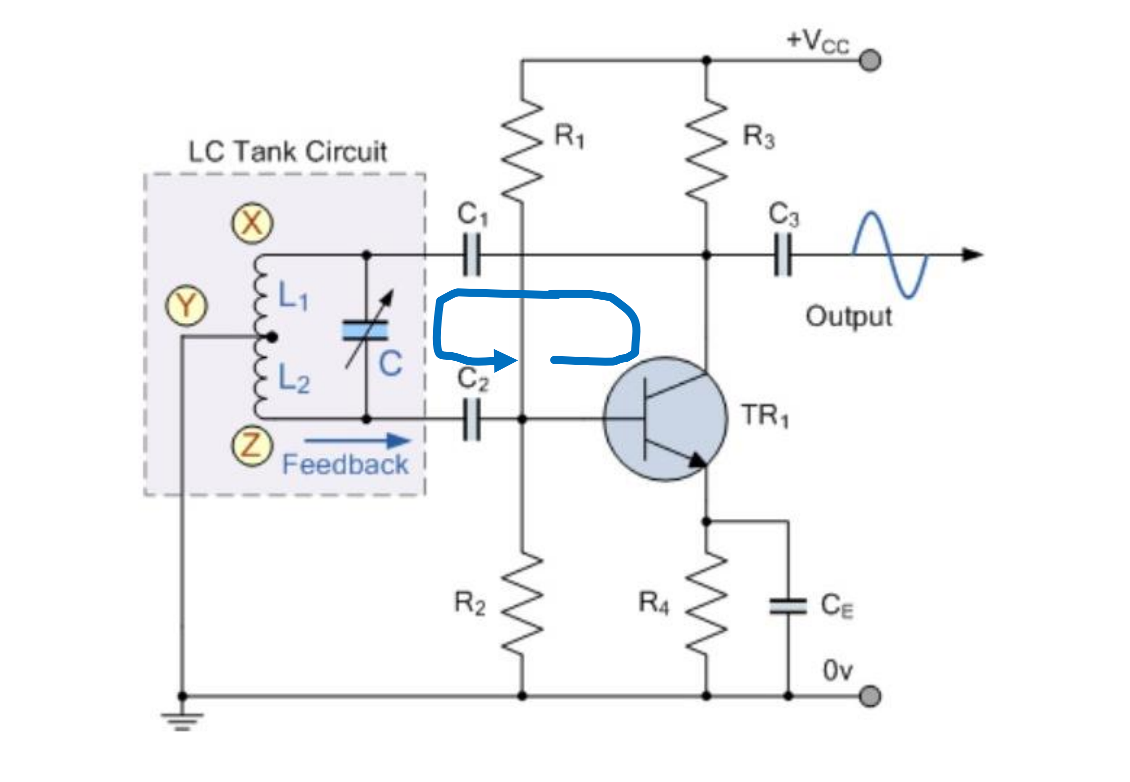


Original patent drawing

Modern Hartley Designs

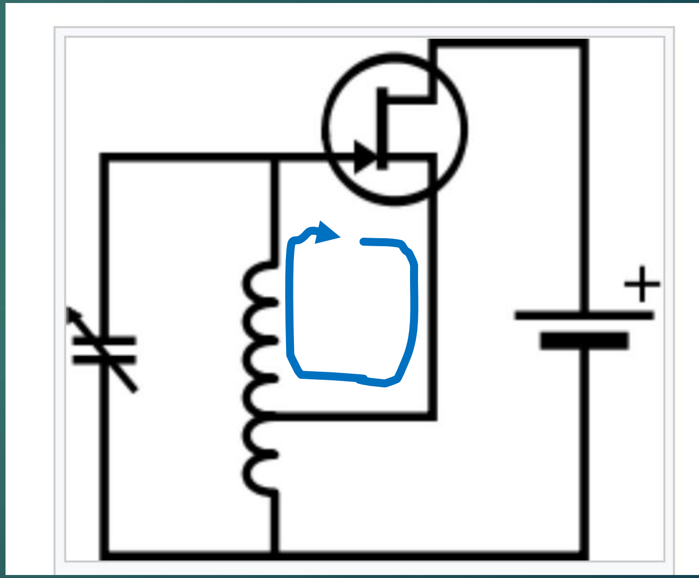
Common-emitter Hartley

https://www.electronics-tutorials.ws/oscillator/hartley.html



Simple Common-drain Hartley

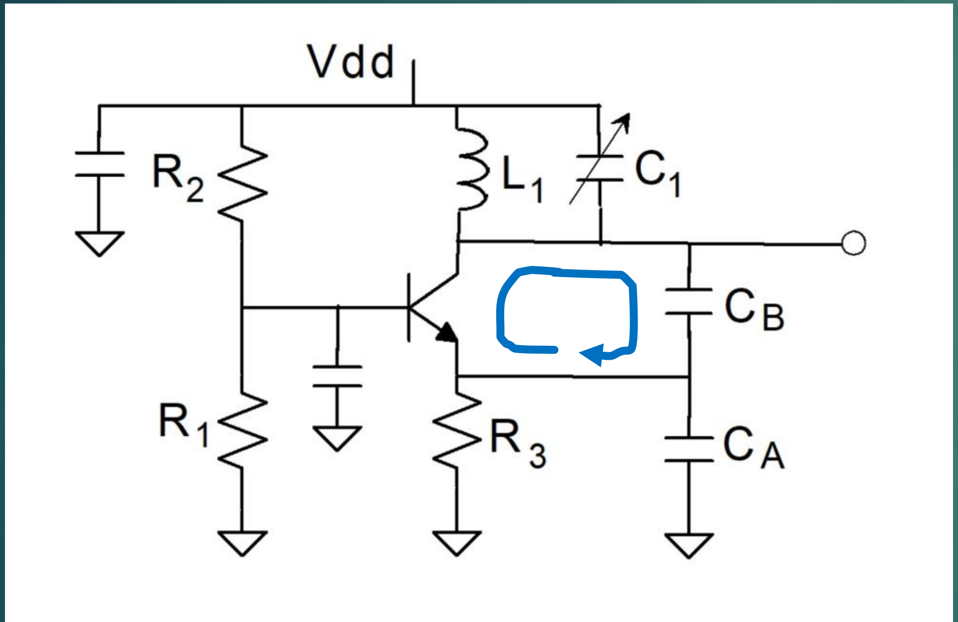
https://en.wikipedia.org/wiki/Hartley_oscillator



Requires two inductors (or tapped inductor) ☹

Modern Colpitts Designs

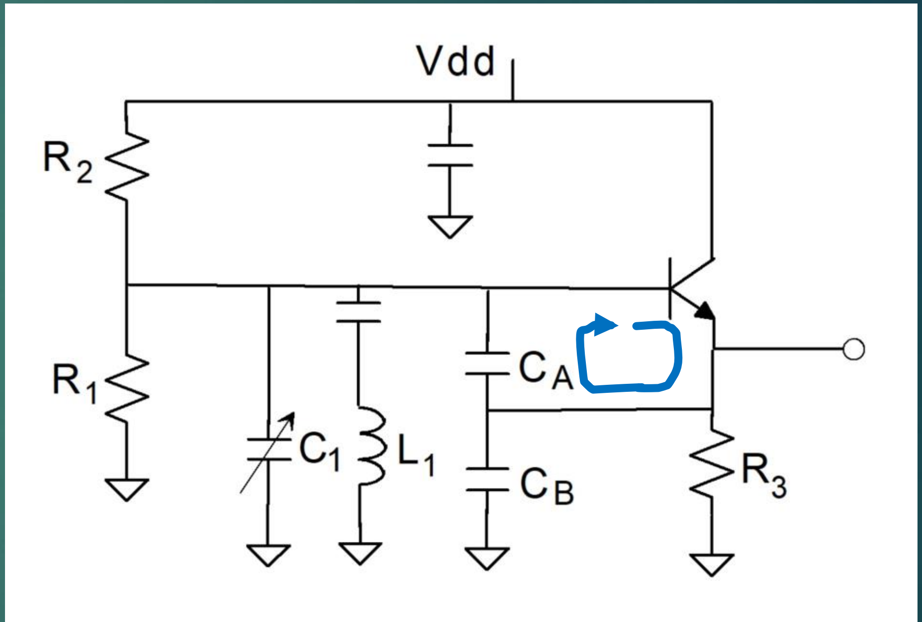
Common-base Colpitts



$$A_{v-open-loop} = +g_m R$$

$Voltage/impedance\ \ step - down\ \ in\ capacitors$

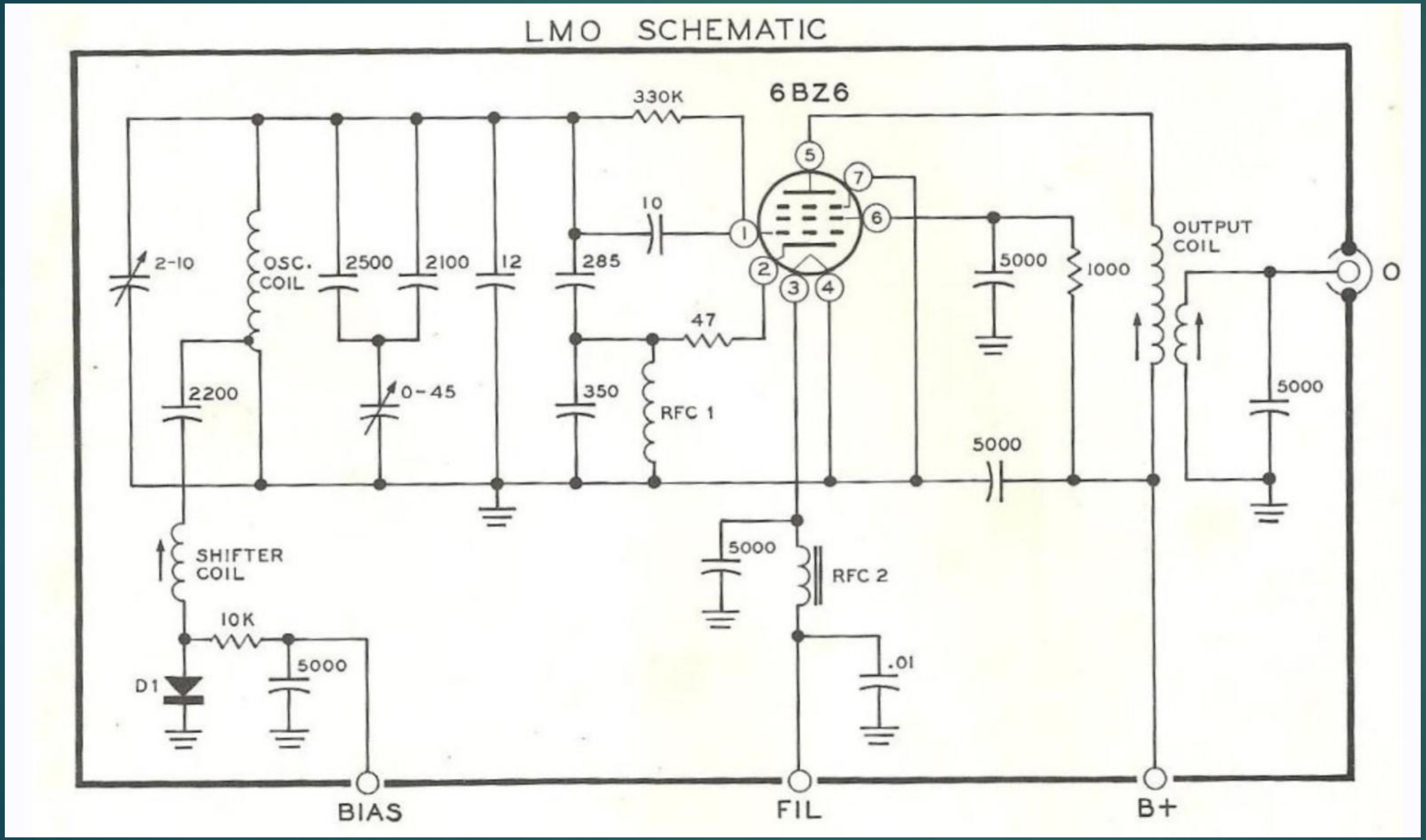
Common-collector Colpitts



$$A_{v-open-loop} = +1$$

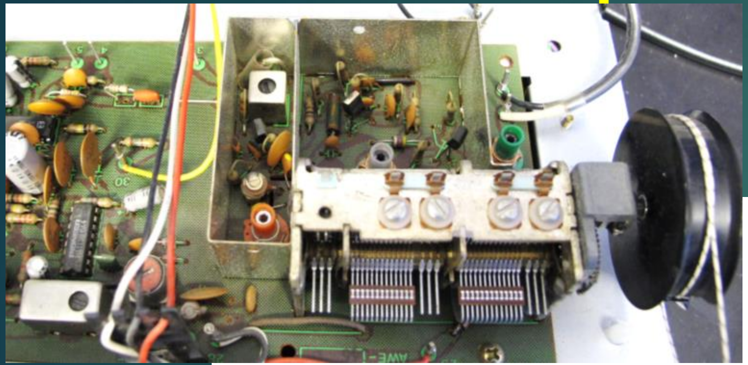
$Voltage/impedance\ \ step - up\ in\ capacitors$
(due to resonance with L1,C1)

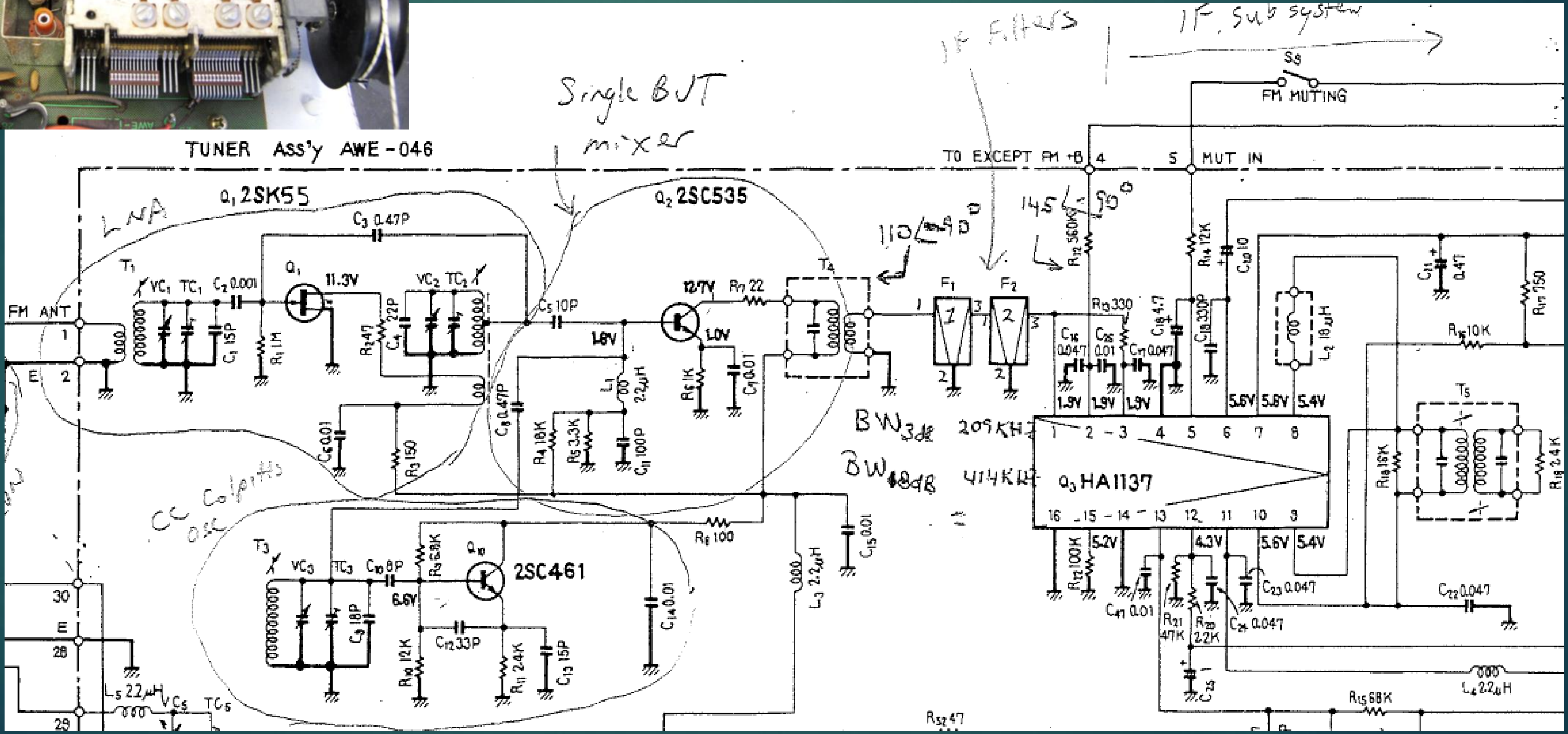
Example 1 – Ham Radio VFO



https://forums.qrz.com/index.php?threads/heathkit-trw-110-48-lmo.747520/

Example 2 – FM Broadcast Receiver





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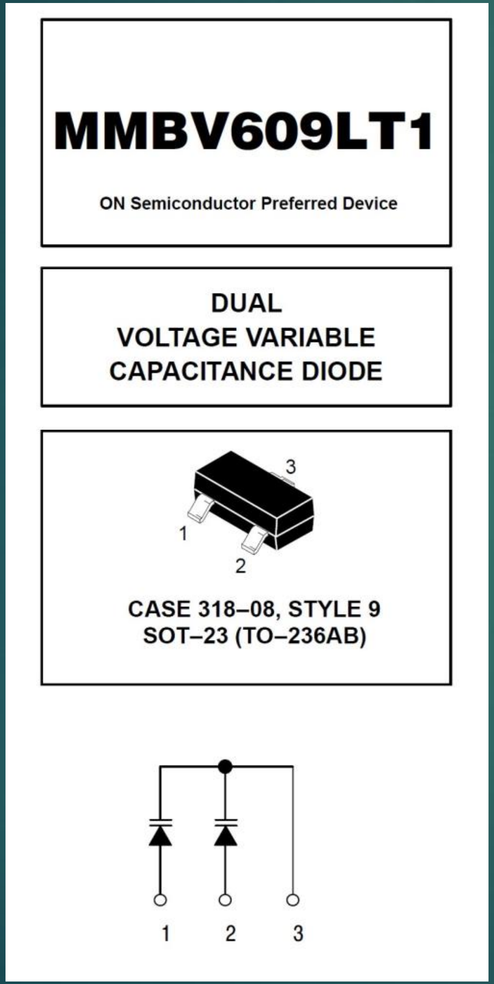
Varactor Diode



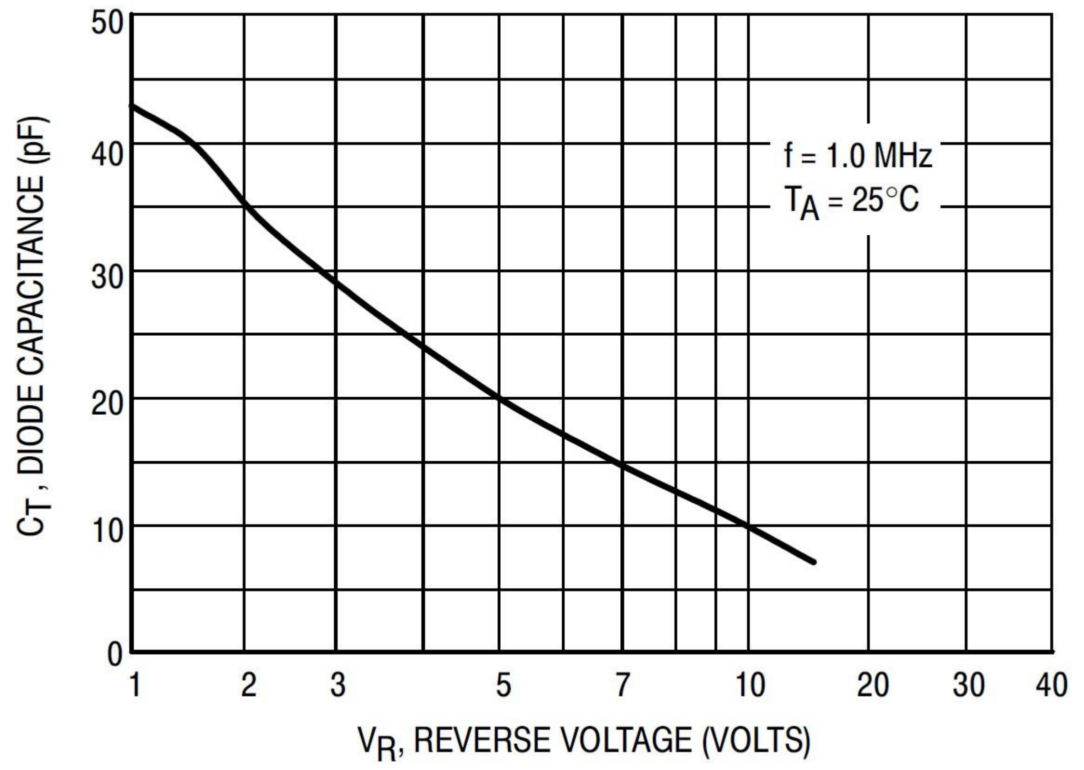
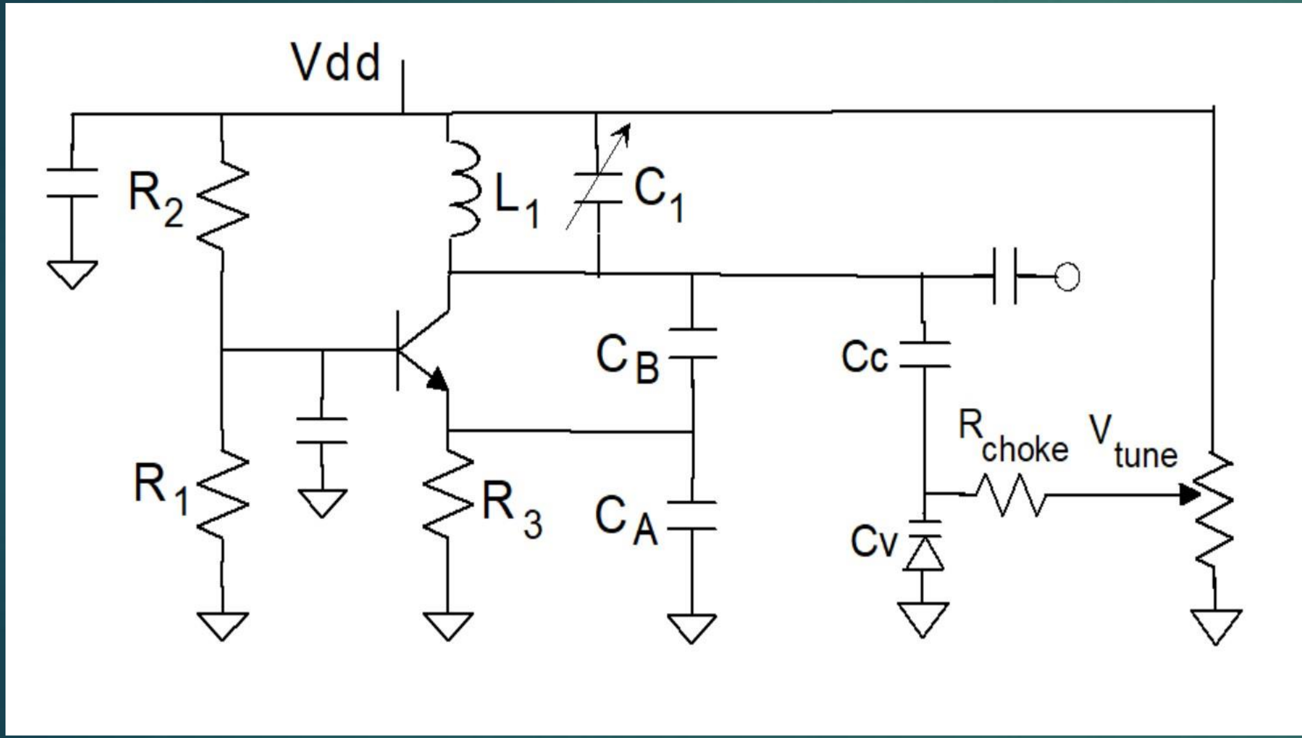


Figure 1. Diode Capacitance

CC Colpitts VCO



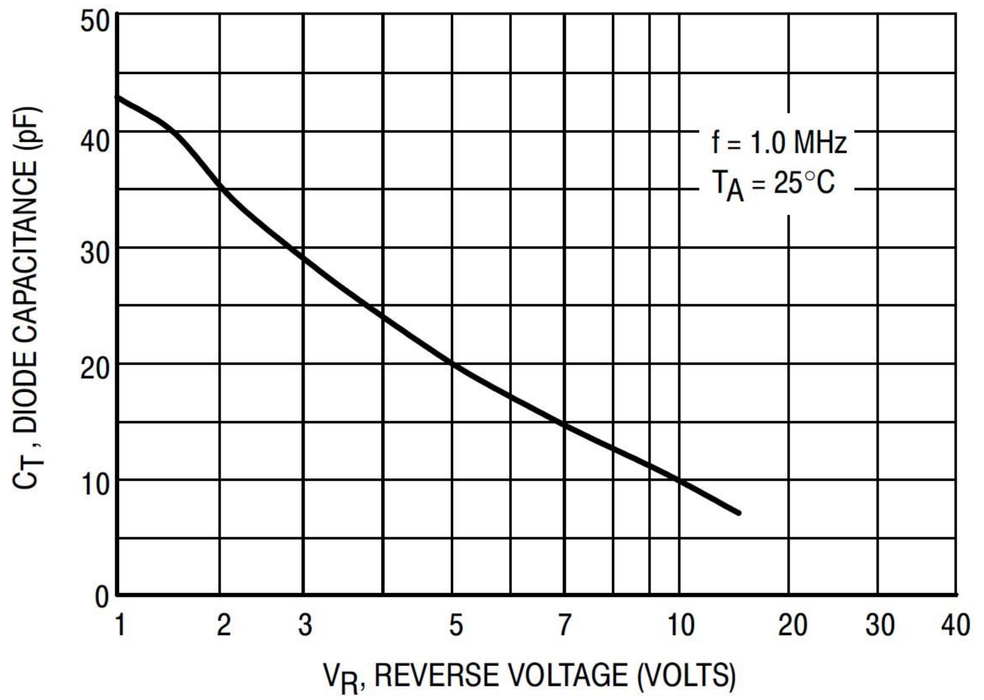


Figure 1. Diode Capacitance

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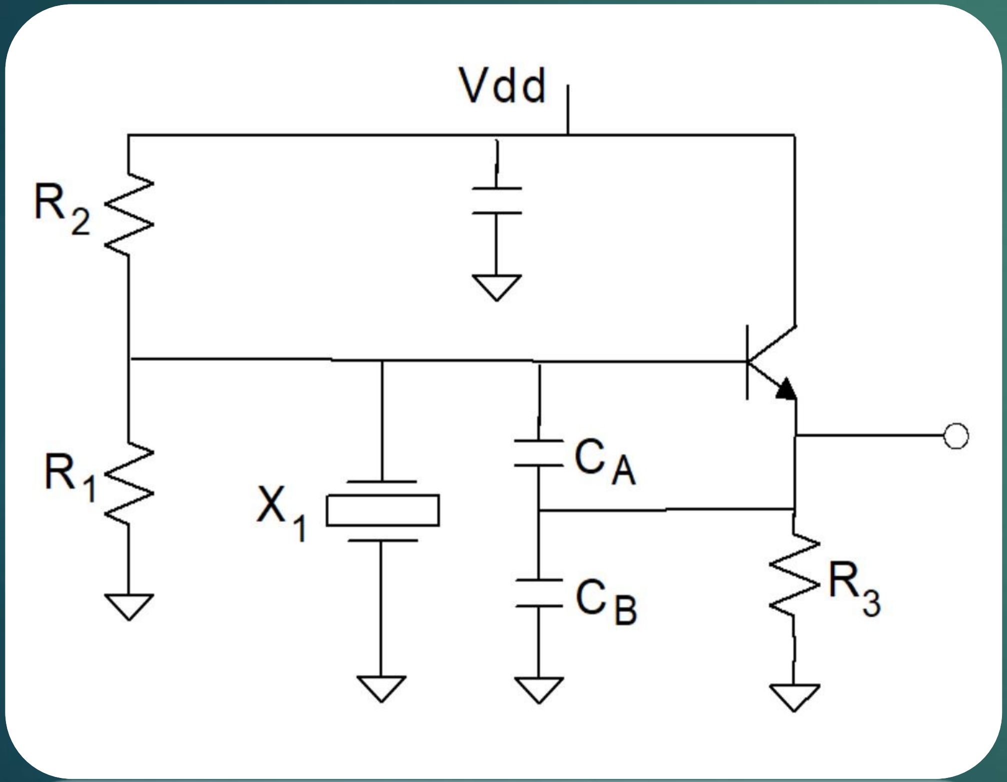
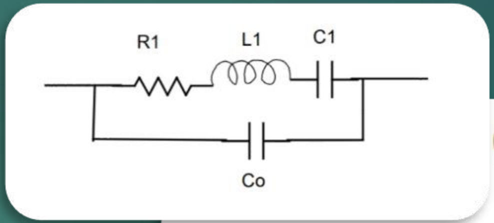
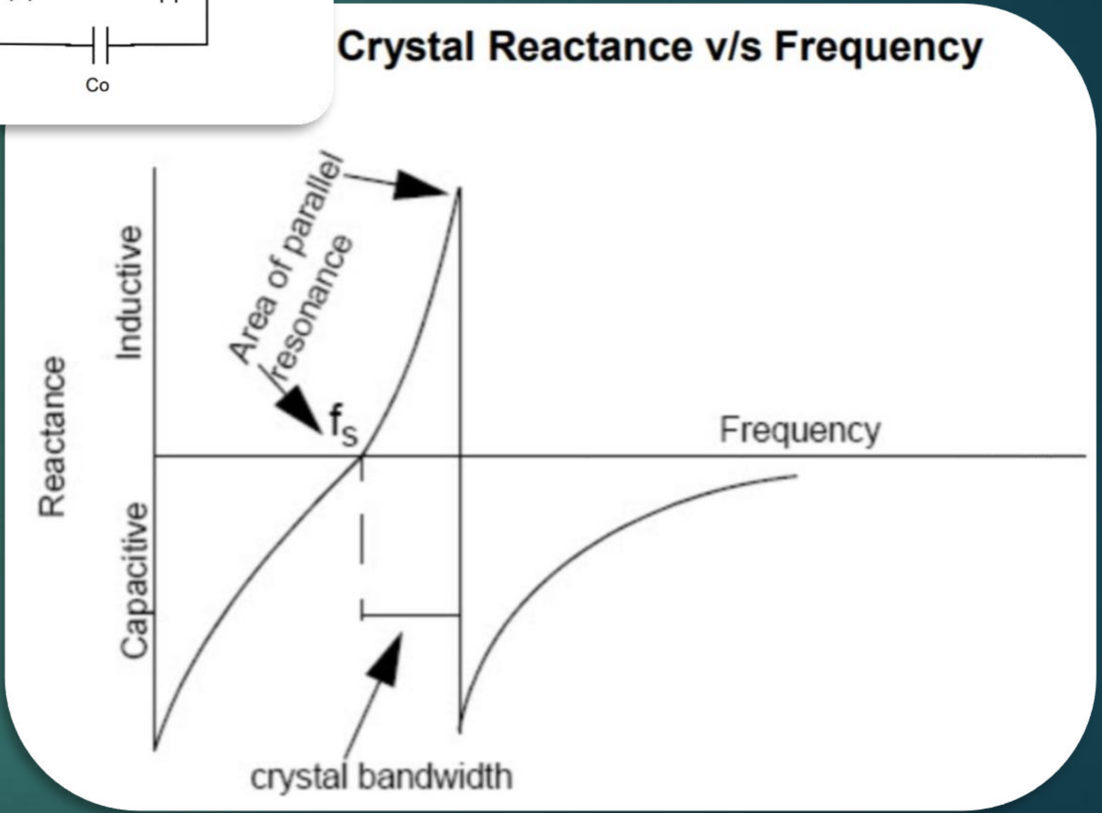
Colpitts Crystal Oscillators







https://www.cypress.com/file/42656/download

TCXOs

HCMOS OUTPUT SMD TCXO

3.2 x 2.5 x 1.0mm

ASTX-H11

ESD Sensitive

RoHS/RoHS II compliant

Moisture Sensitivity Level (MSL)–1

FEATURES:

- HCMOS Output
- Compact and low in height
- Low current consumption; IR reflow possible
- Suitable for high-density SMT

APPLICATIONS:

- Cellular and cordless phones
- Standard OSC for exact equipment
- Mobile communication equipment
- Portable radio equipment and music player

STANDARD SPECIFICATIONS:

Parameters	Minimum	Typical	Maximum	Units	Notes
Frequency Range	2.500		55.000	MHz	
Standard Frequencies	5, 10, 12, 16, 20, 24, 32, 40, 44			MHz	
Operating Temperature	-30		+75	°C	
Storage Temperature:	-40		+125	°C	
Frequency Stability Δf/f0 vs Tolerance (@+25°C)	-2.0		+2.0		1 hr after reflow
vs Temperature (ref. to +25°C)	-2.5		+2.5		See option (Table 1)

Fully Integrated Transceiver

SILICON LABS

Si4430/31/32-B1

Si4430/31/32 ISM Transceiver

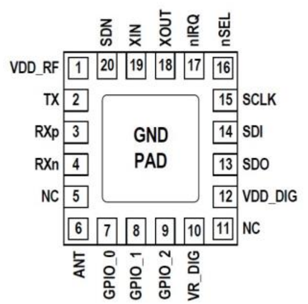
Features

- Frequency Range
  - 240–930 MHz (Si4431/32)
  - 900–960 MHz (Si4430)
- Sensitivity = –121 dBm
- Output power range
  - +20 dBm Max (Si4432)
  - +13 dBm Max (Si4430/31)
- Low Power Consumption
  - 18.5 mA receive
  - 30 mA @ +13 dBm transmit
  - 85 mA @ +20 dBm transmit
- Data Rate = 0.123 to 256 kbps
- FSK, GFSK, and OOK modulation
- Power Supply = 1.8 to 3.6 V
- Ultra low power shutdown mode
- Digital RSSI
- Wake-up timer
- Auto-frequency calibration (AFC)
- Power-on-reset (POR)
- Antenna diversity and TR switch control
- Configurable packet handler
- Preamble detector
- TX and RX 64 byte FIFOs
- Low battery detector
- Temperature sensor and 8-bit ADC
- –40 to +85 °C temperature range
- Integrated voltage regulators
- Frequency hopping capability
- On-chip crystal tuning
- 20-Pin QFN package
- Low BOM

Ordering Information:
See page 67.

Pin Assignments

Si4430/31/32



Patents pending

Applications

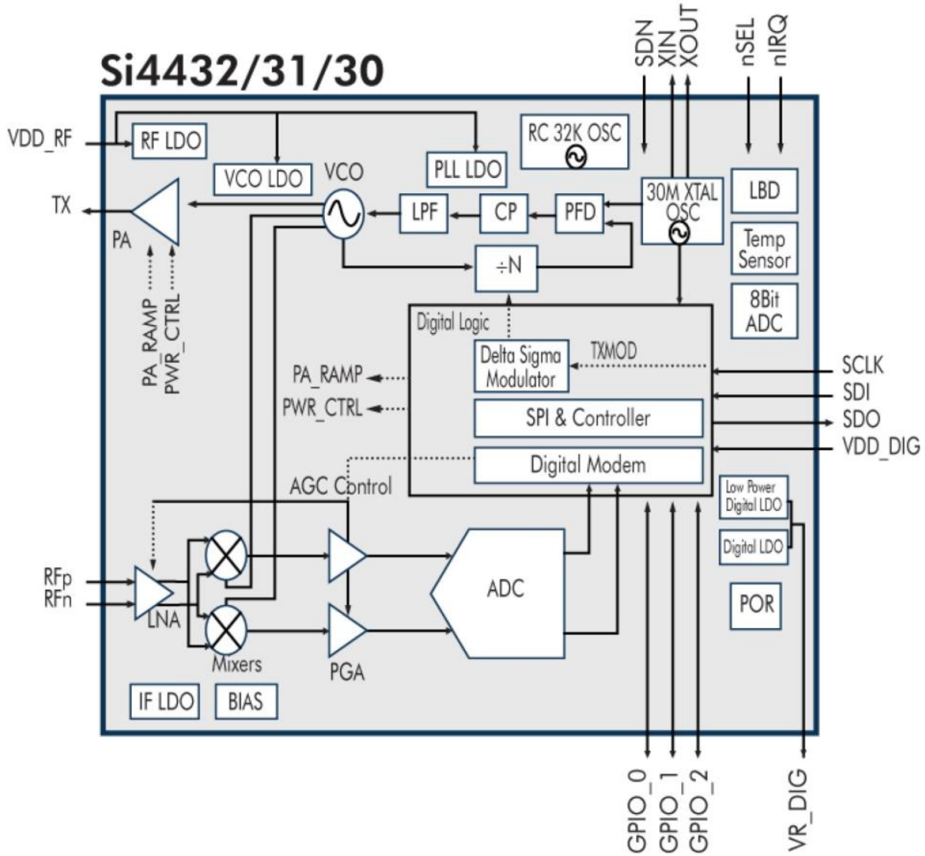
- Remote control
- Home security & alarm
- Telemetry
- Personal data logging
- Toy control
- Tire pressure monitoring
- Wireless PC peripherals
- Remote meter reading
- Remote keyless entry
- Home automation
- Industrial control
- Sensor networks
- Health monitors
- Tag readers

Description

Silicon Laboratories' Si4430/31/32 devices are highly integrated, single chip wireless ISM transceivers. The high-performance EZRadioPRO® family includes a complete line of transmitters, receivers, and transceivers allowing the RF system designer to choose the optimal wireless part for their application.

Si4430/31/32-B1

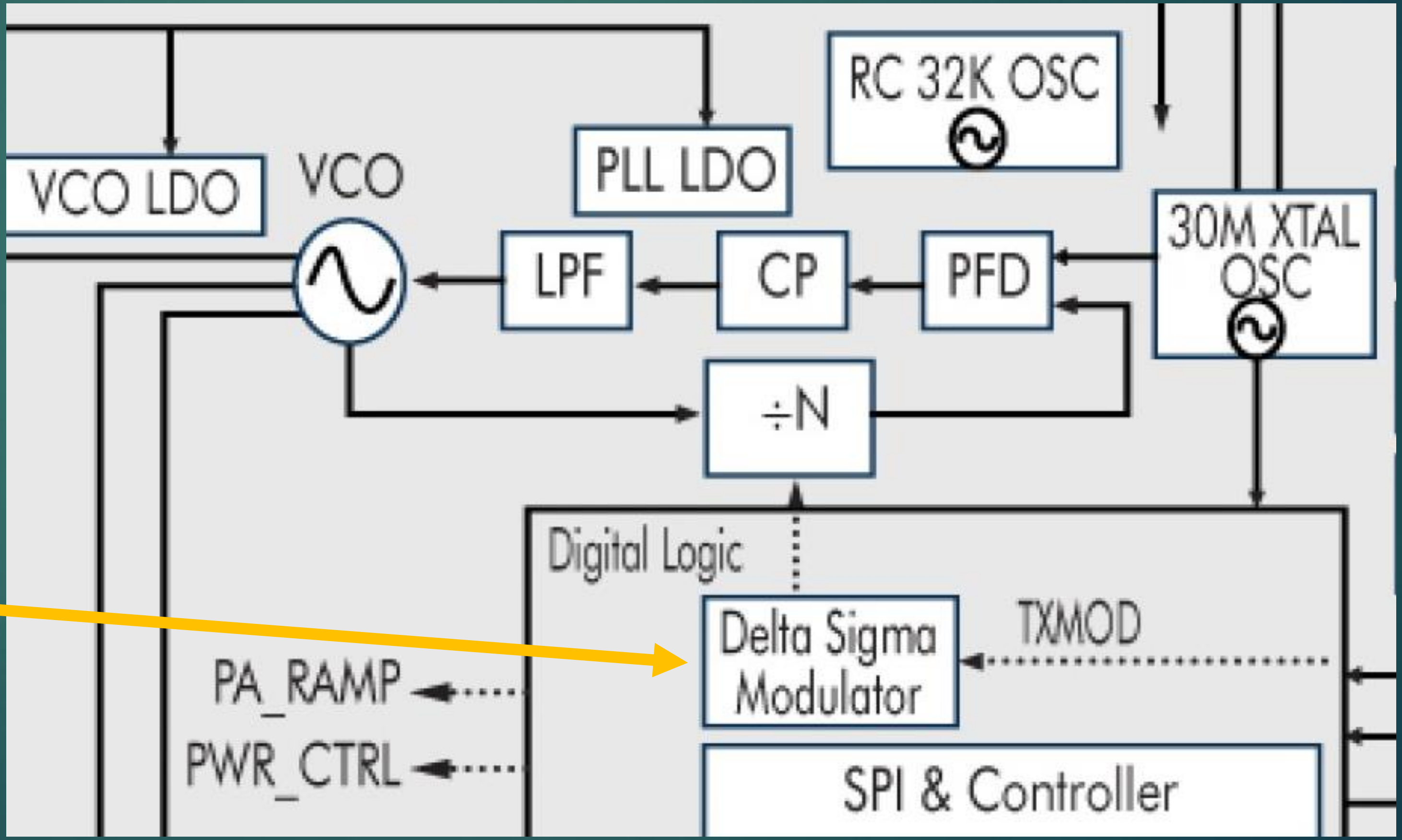
Functional Block Diagram



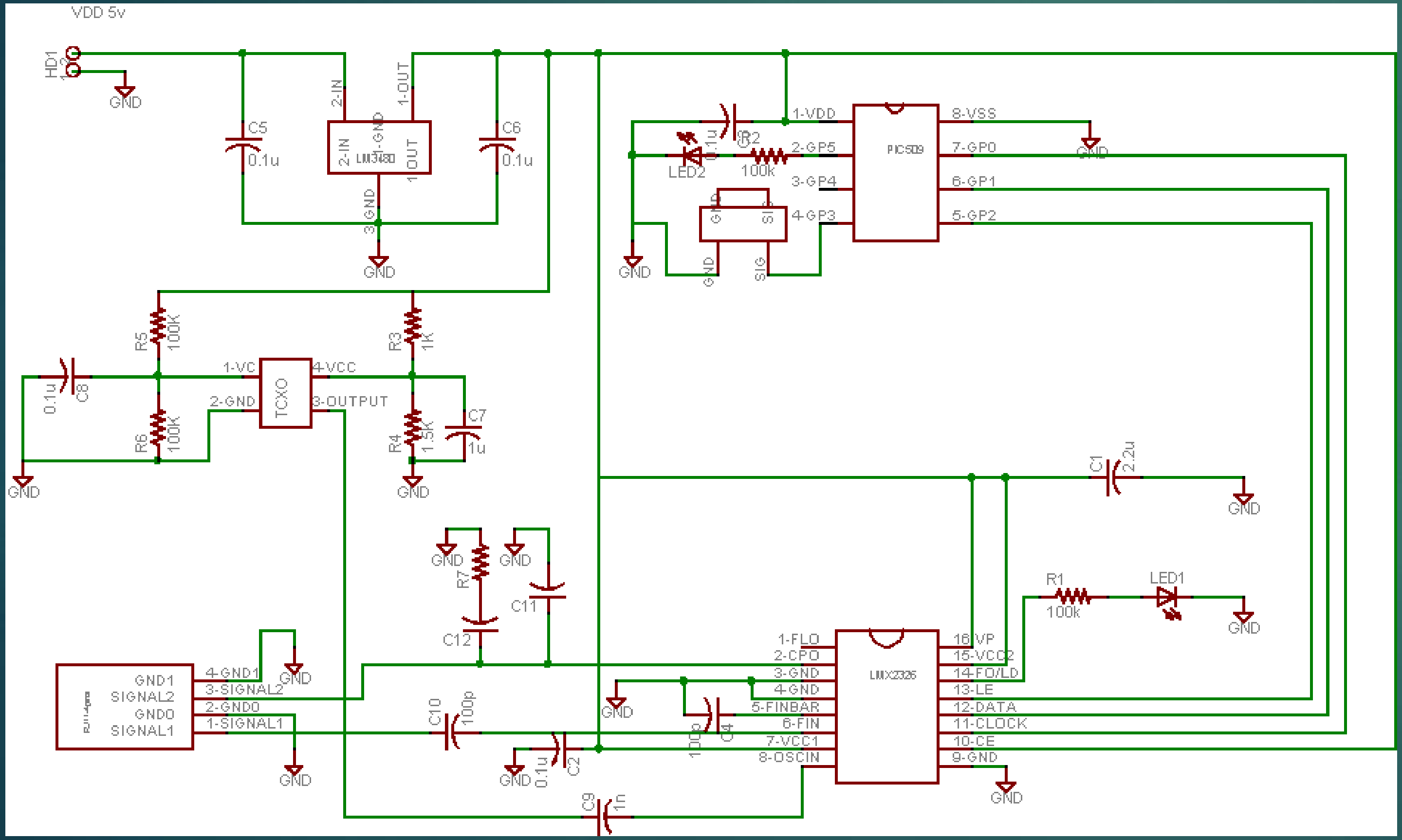
Phase-Locked Loop Synthesizer

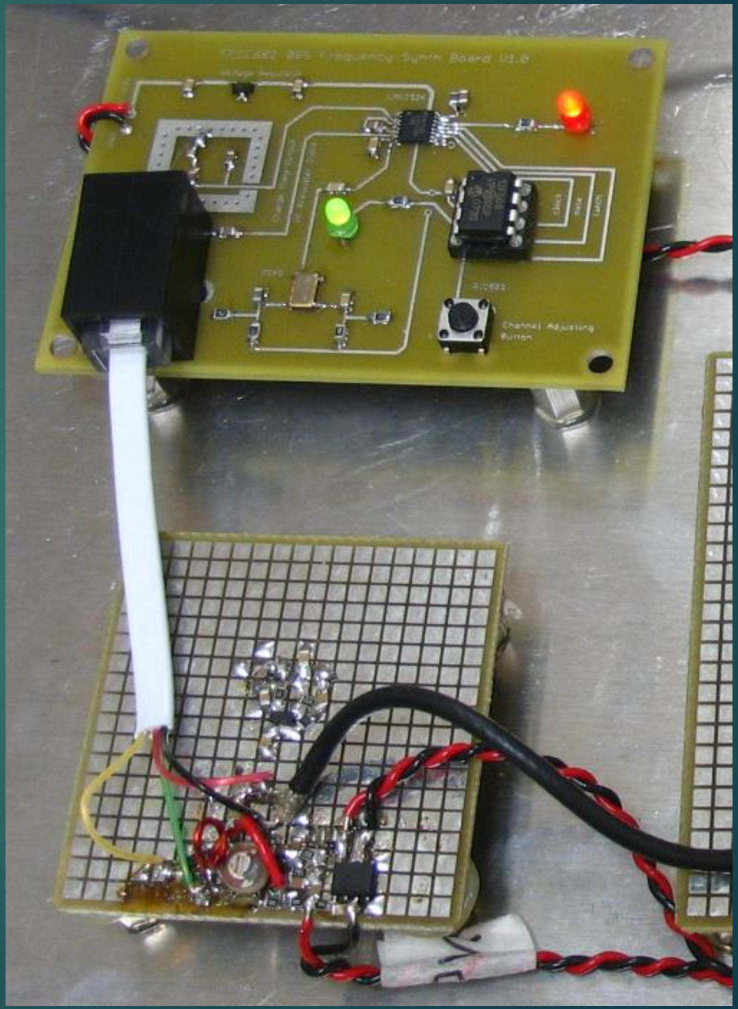
$$f_{out} = N\, f_{ref}$$

"Fractional-N" Architecure



Class FM Receiver Synthesizer





Topic Review

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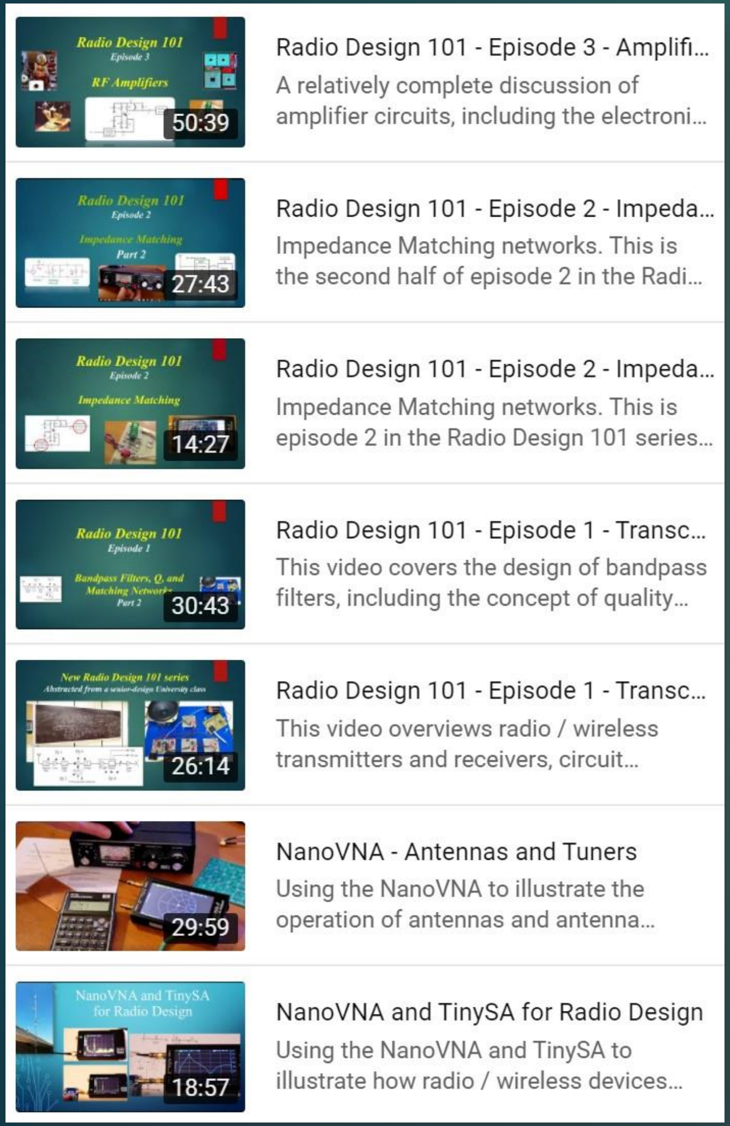
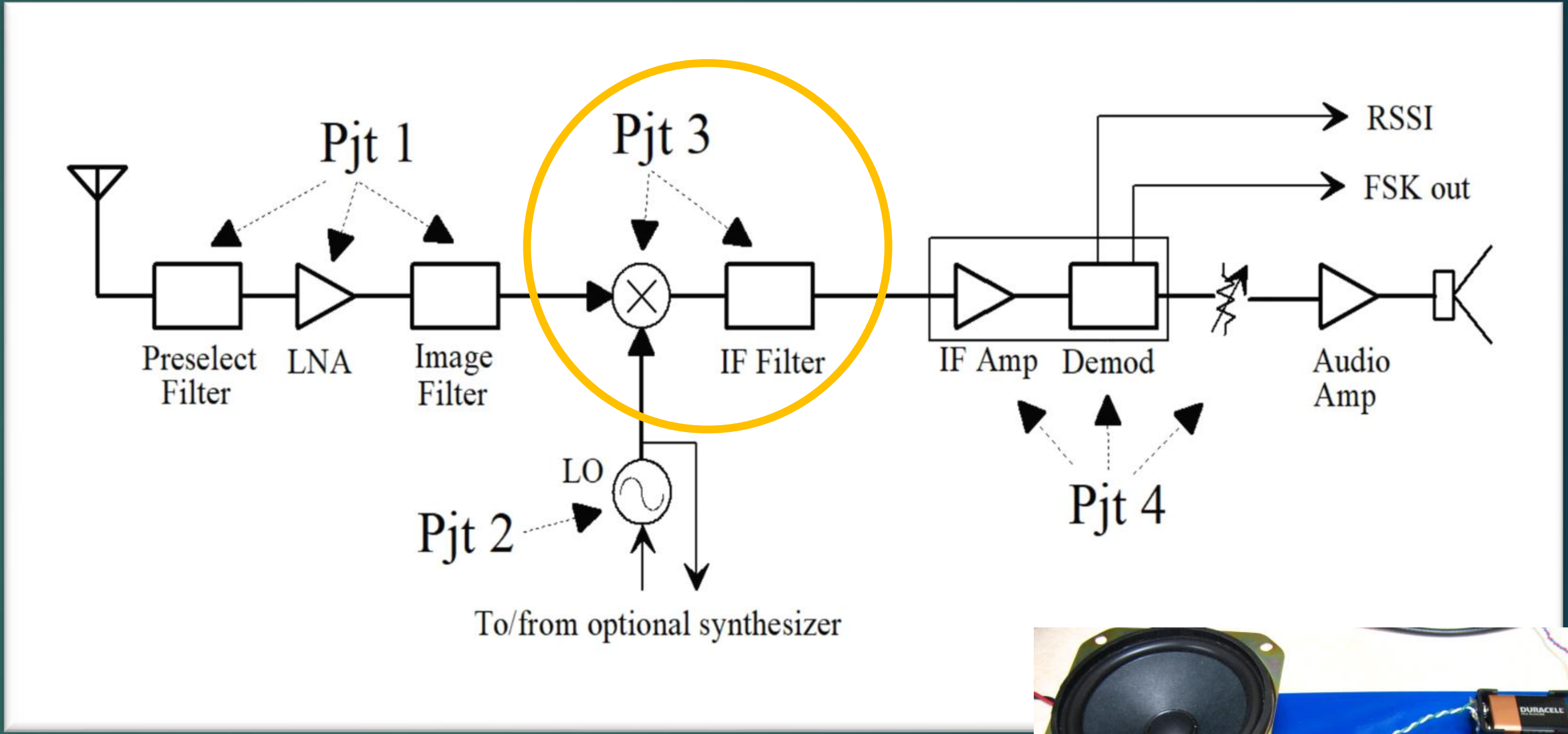
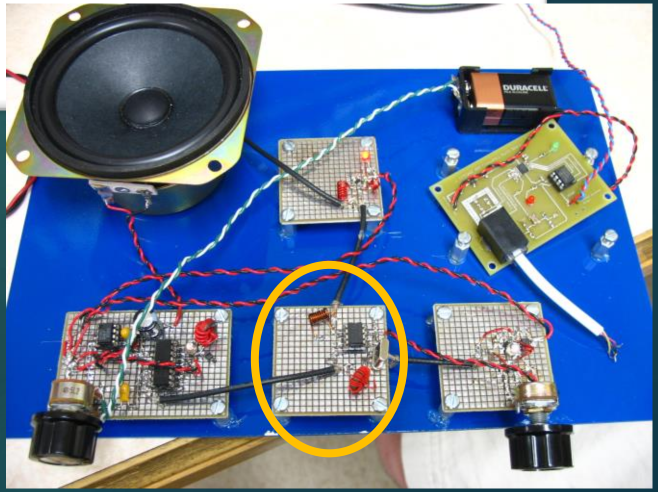
Radio Design 101 "Semester Projects"







Project 3 – Mixer / IF Filter

(Next Video)

Thanks For Watching !