Lecture 8: FM Hardware *and* VCO

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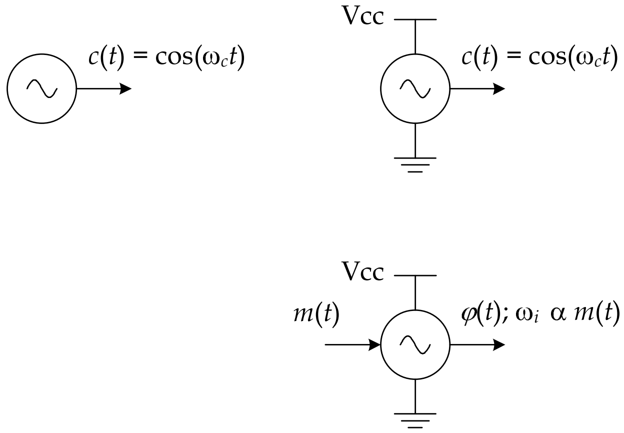
EE423: Communication Electronics

Voltage Controlled Oscillator (VCO): *Modified* Oscillator



VCO Applications

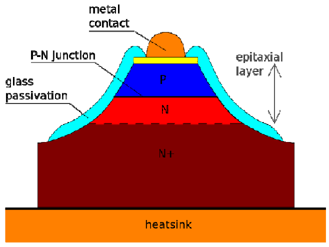
- FM modulator (transmitter).
- VCO is one part in a phase-locked loop (PLL). PLLs have many applications:
  - FM demodulator (receiver).
  - Frequency synthesizer.
  - Stabilizing VCO frequencies in FM transmitters.
  - Clock recovery circuit for digital baseband receivers.
  - Carrier recovery circuit for synchronous demodulators (synchronization).

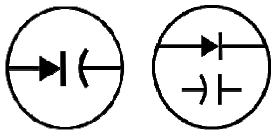
Remember Harmonic Oscillator

- Oscillator has three components:
  - Amplifier
  - Positive feedback
  - LC tank
- The frequency of the oscillator is controlled by the LC tank resonant circuit.
- Changing the capacitance in the LC tank is one popular method to change the instantaneous frequency of the oscillator.

Varactor Diode (Varicap)

- Varactor, Varactor diode, Varicap, Varicap diode, Variable capacitance diode, variable reactance diode, tuning diode.
- Any reverse-biased diode (p–n junction) has voltage-dependent capacitance, but varactors are manufactured to increase such capacitance variation.
- Varactors operate in reverse-bias, so no DC current flows through the device.
- Reverse bias voltage controls thickness of depletion zone and hence the junction capacitance. Capacitance depends on doping profile.





Varactor Datasheet

MOTOROLA

MV1620 thru MV1650 (SILICON)

www.datasheetcatalog.com

CASE 51
(DO-7)

Silicon Epicap diodes, epitaxial passivated tuning diodes designed for AFC applications in radio, TV, and general electronic-tuning.

MAXIMUM RATINGS (T_c = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	20	Volts
Forward Current	I_F	250	mAdc
Device Dissipation @ T_A = 25°C	P_D	400	mW
Derate above 25°C		2.67	mW/°C

Varactor Datasheet

PART NUMBER	CT DIODE CAPACITANCE Vr = 4 Vdc, f = 1 MHz (pF) MIN	NOM	MAX	Q, QUALITY FACTOR Vr = 4 Vdc f = 50 MHz MIN
MV1620	6.1	6.8	7.5	300
MV1622	7.4	8.2	9.0	300
MV1624	9.0	10.0	11.0	300
MV1626	10.8	12.0	13.2	300
MV1628	13.5	15.0	16.5	250
MV1630	16.2	18.0	19.8	250
MV1632	18.0	20.0	22.0	250
MV1634	19.8	22.0	24.2	250
MV1636	24.3	27.0	29.7	200
MV1638	29.7	33.0	36.3	200
MV1640	35.1	39.0	42.9	200
MV1642	42.3	47.0	51.7	200
MV1644	50.4	56.0	61.6	150
MV1646	61.2	68.0	74.8	150
MV1648	73.8	82.0	90.2	150
MV1650	90.0	100.0	110.0	150

Varactor Datasheet

MMBV109LT1, MV209

Preferred Devices

Silicon Epicap Diodes

Designed for general frequency control and tuning applications; providing solid–state reliability in replacement of mechanical tuning methods.

Features

- High Q with Guaranteed Minimum Values at VHF Frequencies
- Controlled and Uniform Tuning Ratio
- Available in Surface Mount Package
- Pb–Free Packages are Available

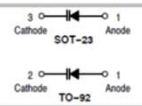
MAXIMUM RATINGS (T_C = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	30	Vdc
Forward Current	I_F	200	mAdc
Forward Power Dissipation	P_D		
MMBV109LT1 @ T_A = 25°C		200	mW
Derate above 25°C		2.0	mW/°C
MV209 @ T_A = 25°C		200	mW
Derate above 25°C		1.6	mW/°C
Junction Temperature	T_J	+125	°C
Storage Temperature Range	T_{stg}	–55 to +150	°C

ON Semiconductor®

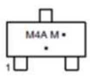
http://onsemi.com

26–32 pF VOLTAGE VARIABLE CAPACITANCE DIODES

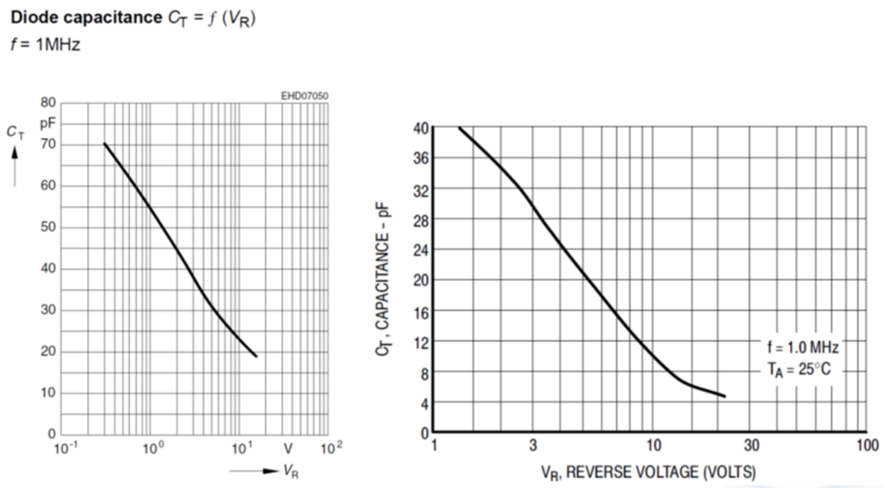


SOT–23 (TO–236)
CASE 318–08
STYLE 8

MARKING DIAGRAMS



Varactor Characteristics



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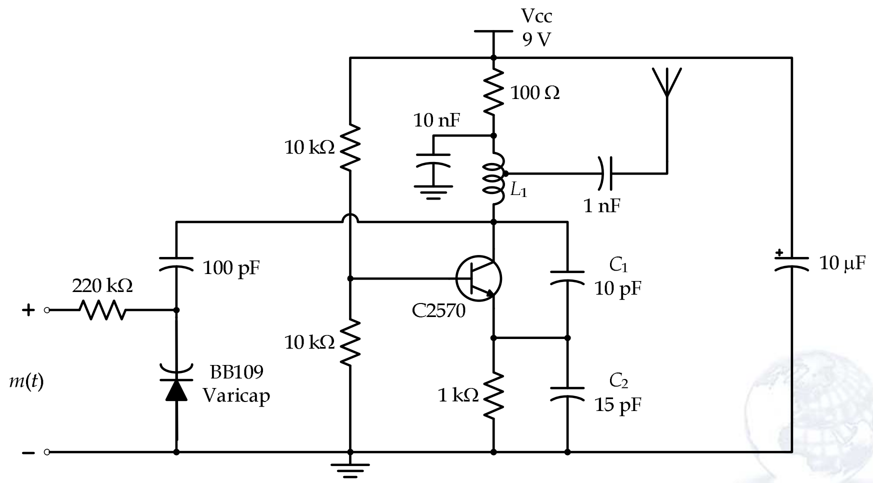
Example VCO: Colpitts



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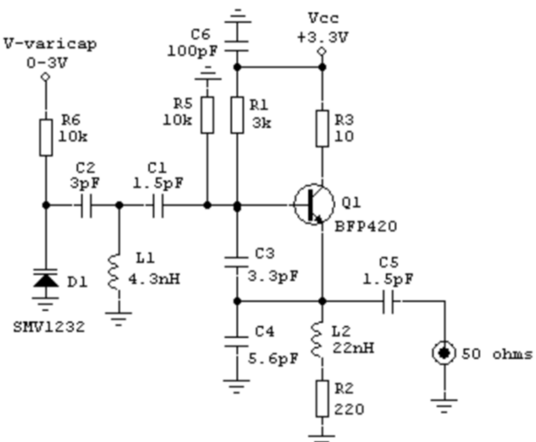
Homework

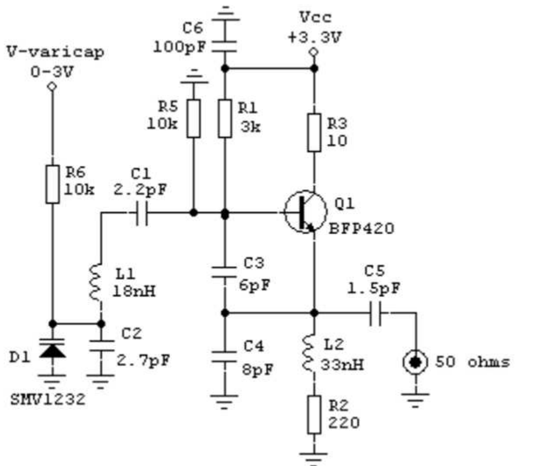
- What is the type of the Oscillator circuit shown above?
- Determine the proper expression for the resonant frequency f_{res} of this oscillator.
  - Neglect the varactor branch (100 pF and C_v).
- Calculate the value of L_1 such that the oscillator frequency is 100 MHz.

Example VCO: Colpitts



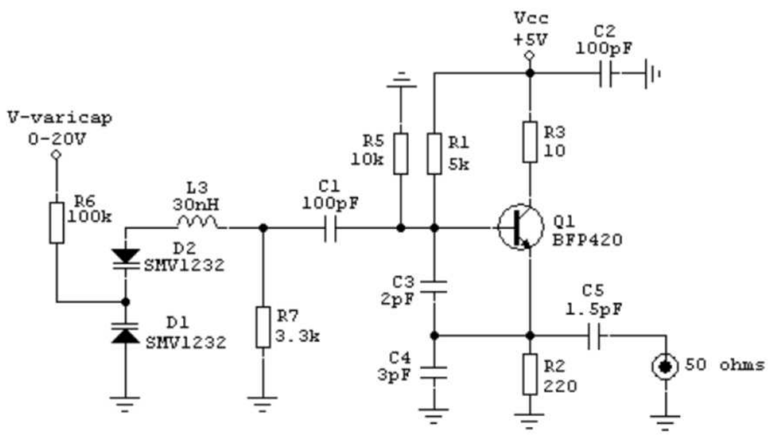
1.52GHz-1.56GHz Colpitts VCO

Example VCO: Clapp



1GHz - 1.2GHz series tuned Colpitts VCO (Clapp VCO)

Wideband Colpitts VCO

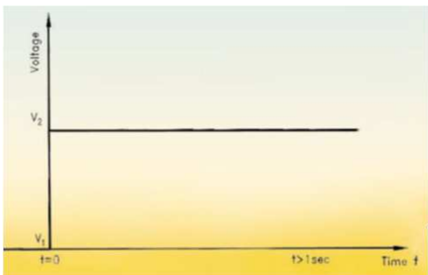


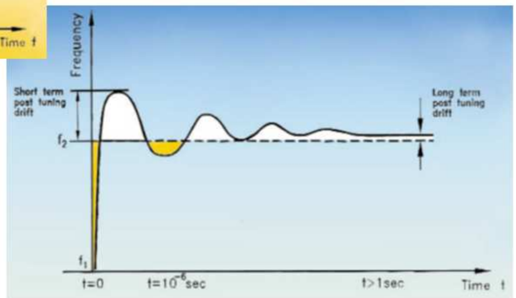
950MHz-2200MHz Colpitts VCO

VCO Terminology

- **Frequency Tuning Characteristic:** The frequency versus tuning voltage graph.
- **Tuning Sensitivity:** Slope of tuning characteristic, expressed as frequency change per unit voltage change (e.g., MHz/V).
- **Tuning Linearity:** The deviation of frequency versus tuning voltage characteristic from a best-fit straight line.
- **Tuning Speed (or Response Time):** Time required for the output frequency to settle to within 90 percent of its final value after applying a step change in voltage. The application of step voltage causes the VCO to change its frequency from initial f_1 to final f_2 value. The frequency f_2 will settle to a stabilized value after some time.
- **Post Tuning Drift:** Frequency error compared to the final stabilized value at a specified time after the application of a step voltage. Expressed as frequency error in Hz, kHz, etc.

Response Time & Post Tuning Drift





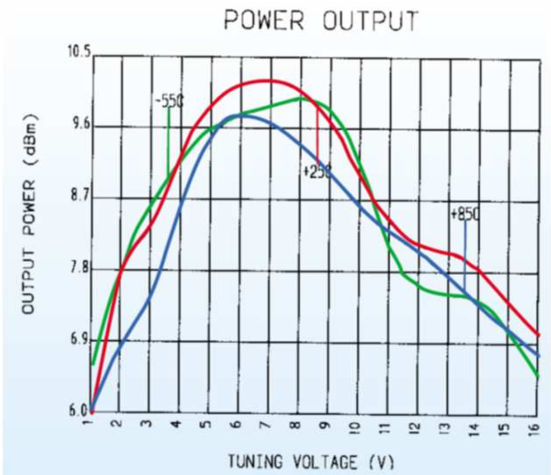
VCO Parameters

- **Frequency Drift with Temperature:** Frequency drift of VCO with temperature at a fixed tuning voltage, expressed as relative percentage change per unit temperature, or as frequency change per unit temperature.
- **Frequency Push:** Frequency variation caused by changes to the supply voltage at a fixed tuning voltage (expressed in MHz per volt).
- **Frequency Pull:** Frequency variation caused by changes due to the output load. Usually specified at a load return loss of 12dB and all possible phases.
- **Q or Quality Factor:** Describes the sharpness of a tuned circuit response. A high Q circuit has a sharper response, and vice versa.

VCO Design Considerations

- **Output Power:** Power of fundamental sinusoidal frequency output, measured into a 50 ohm load.
- **Output Power Flatness:** Variation of output power from average output power over the specified frequency range, expressed in dB.
- **Output Power Change with Temperature:** Change in output power with temperature.
- **Harmonic Content or Suppression:** Extra harmonics measured relative to the fundamental signal, expressed in dB referenced to the carrier (dBc).
- **Spurious Responses:** Spurious frequencies are unwanted and non-harmonically related signals. Usually expressed in dBc.
- **SSB Phase Noise:** Single sideband phase noise in 1Hz bandwidth, measured relative to carrier power at a given offset from the carrier frequency and is expressed as dBc/Hz.

Output Power & Change with Temperature (Datasheet)



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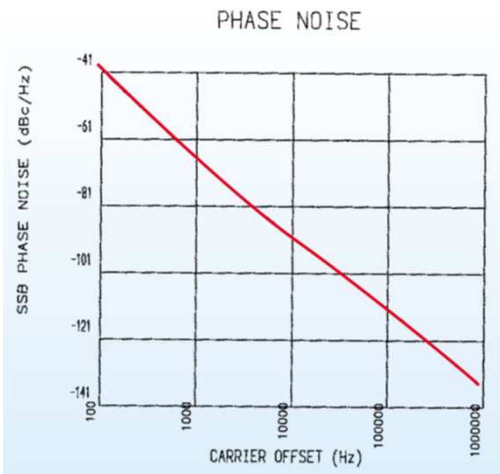
SSB Phase Noise (Datasheet)



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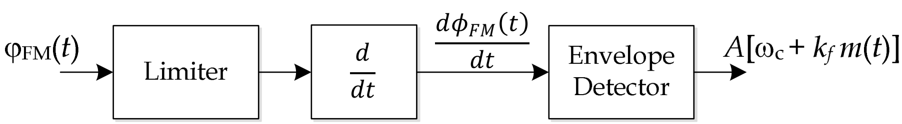
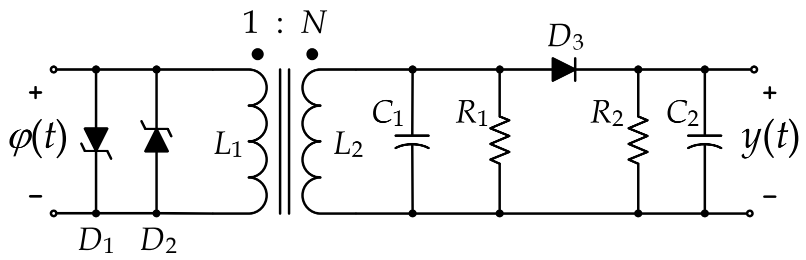
FM Demodulators

- FM Discriminator (also called Slope Detector or Ratio Detector):
  - Convert frequency variations into amplitude variations, then use an envelope detector.
- Quadrature Detector:
  - Convert frequency variations into phase variations, then use a phase-difference detector.
- Phase-Locked Loop:
  - A phase-difference feedback system.

FM Discriminator
(aka Slope Detector or Ratio Detector)



Example Circuit



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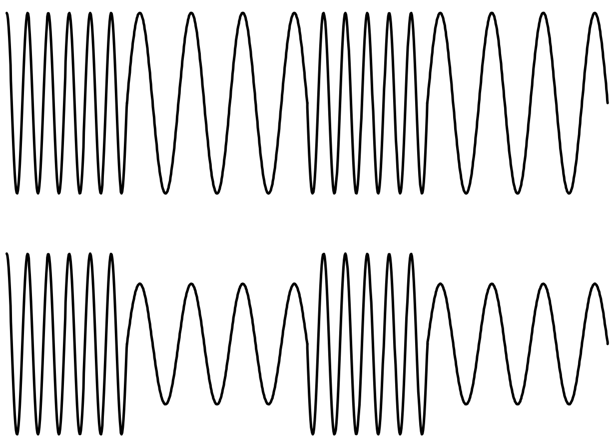
(FM) into (FM+AM)



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Quadrature Detector