Class C Amplifier

- Class C amplifier operates for less than half of the input cycle. It’s efficiency is about 75% because the active device is biased beyond cutoff.
- It is commonly used in RF circuits where a resonant circuit must be placed at the output in order to keep the sine wave going during the non-conducting portion of the input cycle.

Types of Signal Distortion

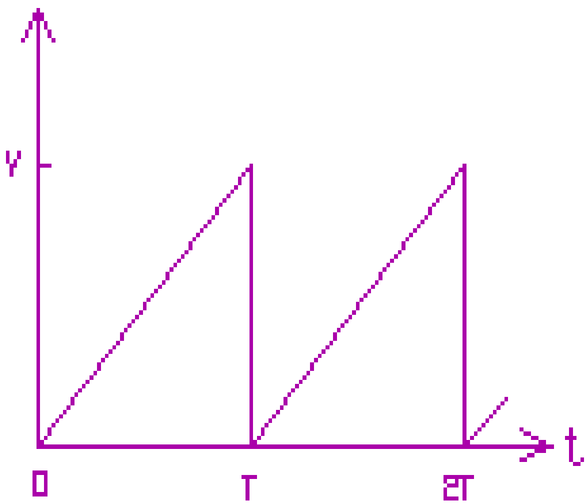
Types of distortion in communications:

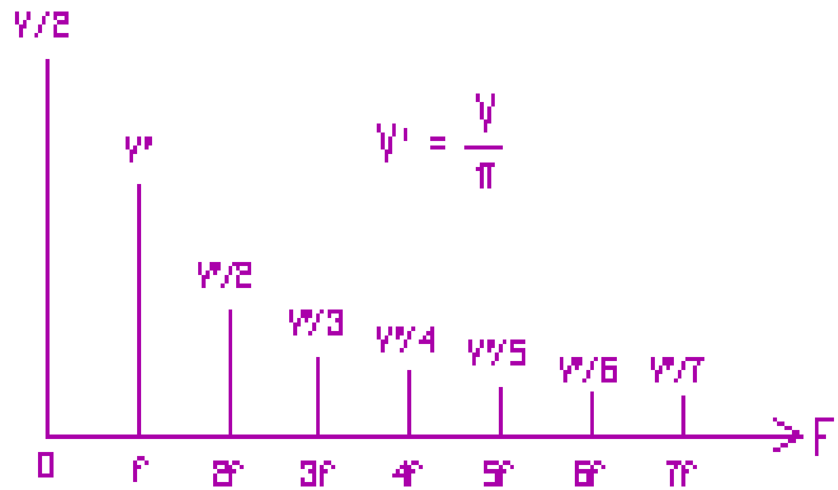
- harmonic distortion
- intermodulation distortion
- nonlinear frequency response
- nonlinear phase response
- noise
- interference

Non-sinusoidal Waveform

- Any well-behaved periodic waveform can be represented as a series of sine and/or cosine waves plus (sometimes) a dc offset:

$e(t)=C_o+\Sigma A_n \cos n\omega t + \Sigma B_n \sin n\omega t$ (Fourier series)





External Noise

- Equipment / Man-made Noise is generated by any equipment that operates with electricity
- Atmospheric Noise is often caused by lightning
- Space Noise is strongest from the sun and, at a much lesser degree, from other stars

Internal Noise

- Thermal Noise is produced by the random motion of electrons in a conductor due to heat. Noise power, $P_N = kTB$

where T = absolute temperature in ^{o}K

k = Boltzmann's constant, 1.38×10^{-23} J/K

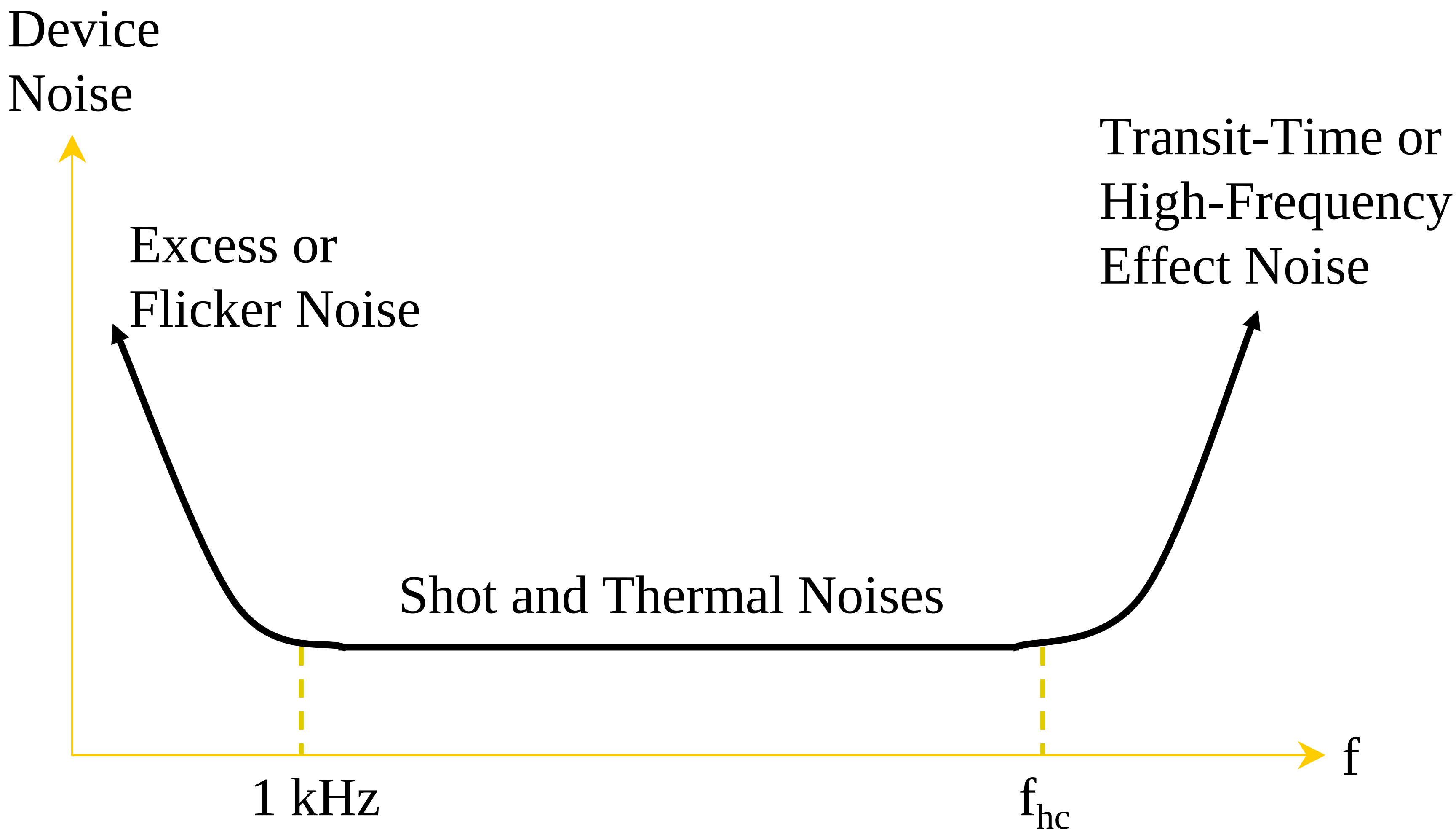
B = noise power bandwidth in Hz

Noise voltage, $V_N = \sqrt{4kTBR}$

Internal Noise (cont'd)

- Shot Noise is due to random variations in current flow in active devices.
- Partition Noise occurs only in devices where a single current separates into two or more paths, e.g. bipolar transistor.
- Excess Noise is believed to be caused by variations in carrier density in components.
- Transit-Time Noise occurs only at high f.

Noise Spectrum of Electronic Devices



Noise Figure

- Noise Figure is a figure of merit that indicates how much a component, or a stage degrades the SNR of a system:

$$NF = (S/N)_i \,/\, (S/N)_o$$

where $(S/N)_i$ = input SNR (not in dB)

and $(S/N)_o$ = output SNR (not in dB)

$$NF(dB) = 10 \log NF = (S/N)_i\,(dB) - (S/N)_o\,(dB)$$

Equivalent Noise Temperature and Cascaded Stages

- The equivalent noise temperature is very useful in microwave and satellite receivers.

$$T_{eq} = (NF - 1)T_o$$

where T_o is a ref. temperature (often 290 ^{o}K)

- When two or more stages are cascaded:

$$NF_T = NF_1 + \frac{NF_2 - 1}{A_1} + \frac{NF_3 - 1}{A_1 A_2} + \dots$$

Class C Amplifier

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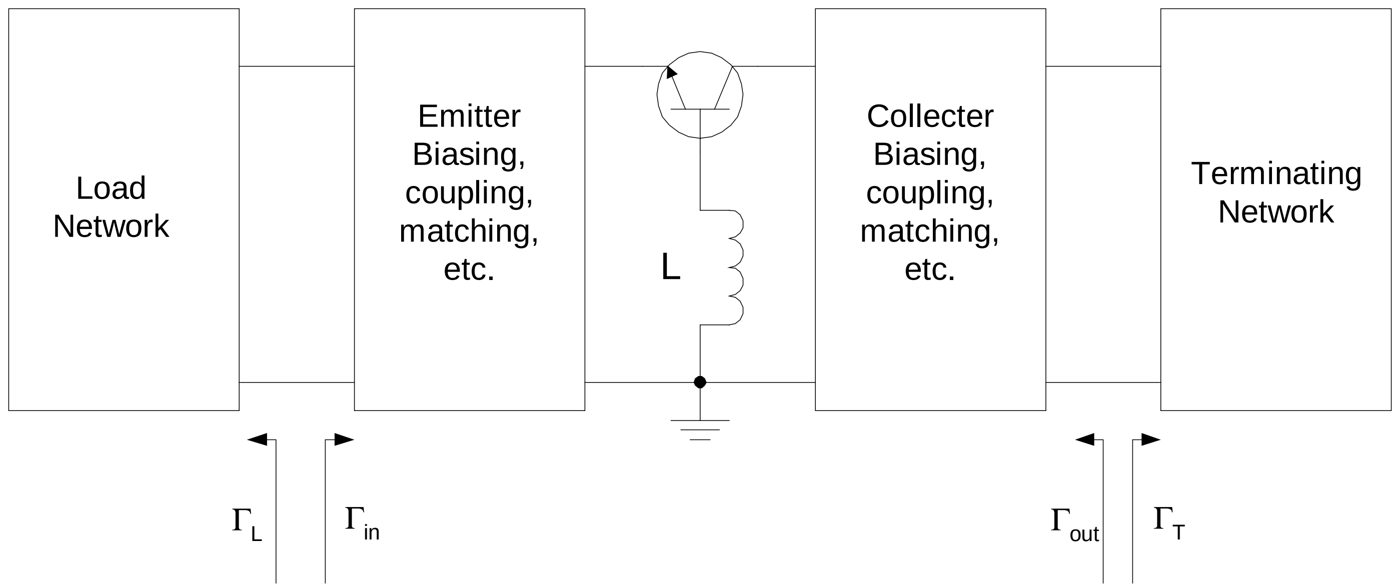
Simple Oscillator Using Stability



Choose transistor (BJT or FET) wisely so that common-base S_{11} > 1 and S_{22} >1 at oscillation frequency: This will cause instability.

NE021 npn High Frequency BJT

NE02100

V_{CE} = 10 V, I_C = 5 mA

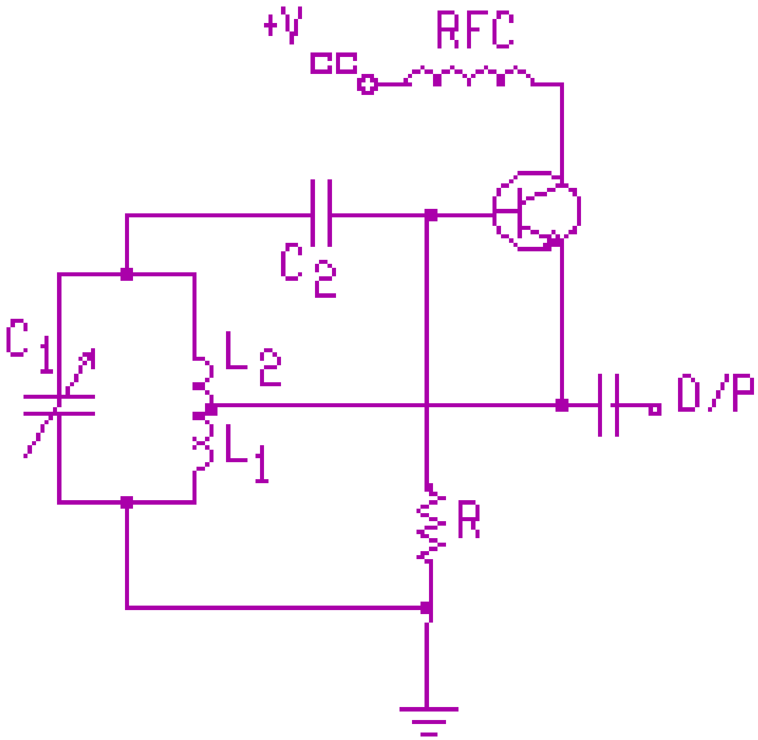
FREQUENCY	S_{11}		S_{21}		S_{12}		S_{22}		K	MAG[2]
(MHz)	MAG	ANG	MAG	ANG	MAG	ANG	MAG	ANG		(dB)
100	.84	-32	11.83	160	.03	70	.94	-16	.11	26.4
500	.75	-114	7.22	113	.07	36	.56	-45	.29	19.9
1000	.73	-150	4.13	89	.09	27	.39	-51	.54	16.9
1500	.71	-164	2.85	76	.09	27	.36	-56	.77	15.0
2000	.71	-173	2.16	66	.10	28	.33	-61	.97	13.5
2500	.71	-179	1.75	57	.10	30	.33	-67	1.14	10.1 ←
3000	.70	176	1.49	49	.11	32	.34	-73	1.25	8.3
3500	.70	172	1.28	42	.12	33	.35	-80	1.35	6.9
4000	.70	168	1.13	34	.12	34	.37	-88	1.41	5.9
4500	.70	165	1.02	27	.13	34	.39	-94	1.47	4.9
5000	.70	161	.92	20	.14	35	.41	-100	1.49	4.2
V_{CE} = 10 V, I_C = 10 mA										
100	.75	-47	20.04	153	.02	65	.89	-24	.11	29.2
500	.72	-137	9.40	105	.05	34	.41	-57	.39	22.5
1000	.72	-162	4.97	86	.06	34	.27	-62	.69	19.0
1500	.71	-173	3.37	75	.07	38	.23	-66	.92	16.8
2000	.71	-179	2.56	66	.08	41	.22	-71	1.09	13.2 ←
2500	.71	176	2.05	58	.09	43	.23	-76	1.19	10.9
3000	.71	172	1.74	51	.10	44	.24	-82	1.27	9.2
3500	.71	168	1.50	44	.11	44	.25	-88	1.31	7.9
4000	.70	165	1.33	37	.12	44	.27	-95	1.36	6.8
4500	.70	162	1.19	30	.13	44	.29	-100	1.39	5.9
5000	.70	159	1.08	24	.14	43	.31	-106	1.39	5.1

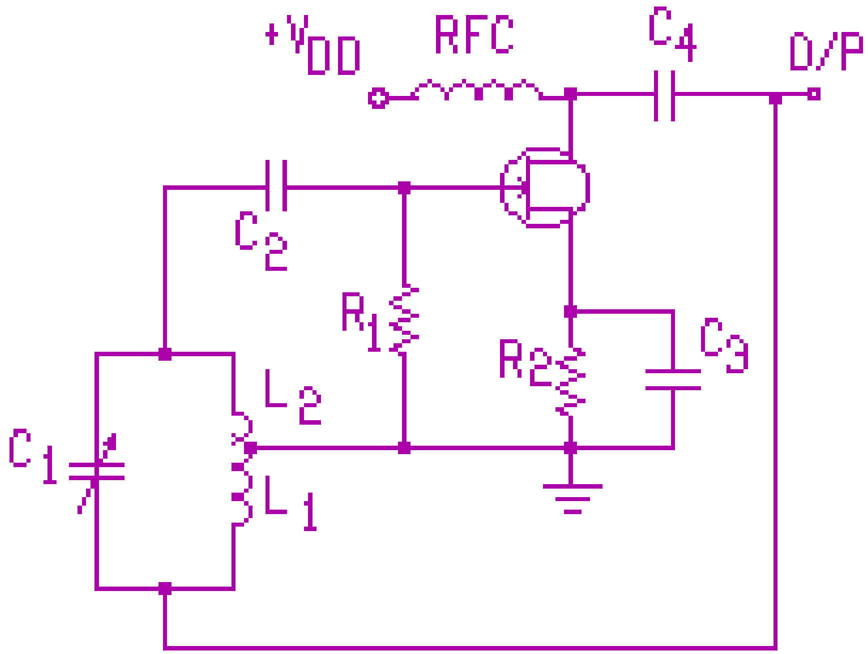
$S_{22} > 1$: Potential Instability

Simple Oscillator Design: KISS!

- Select transistor that is potentially unstable at oscillation frequency
- Chose GT for terminating network that will make |GIN|>1
- Calculate GL for the load network that will resonate ZIN at oscillation frequency
- If $Z_{IN} = R_{IN} + jX_{IN}$, then $Z_L = R_L + jX_L$, where $R_L = |R_{IN}|\ /3$ and $X_L = -X_{IN}$

Hartley Oscillators



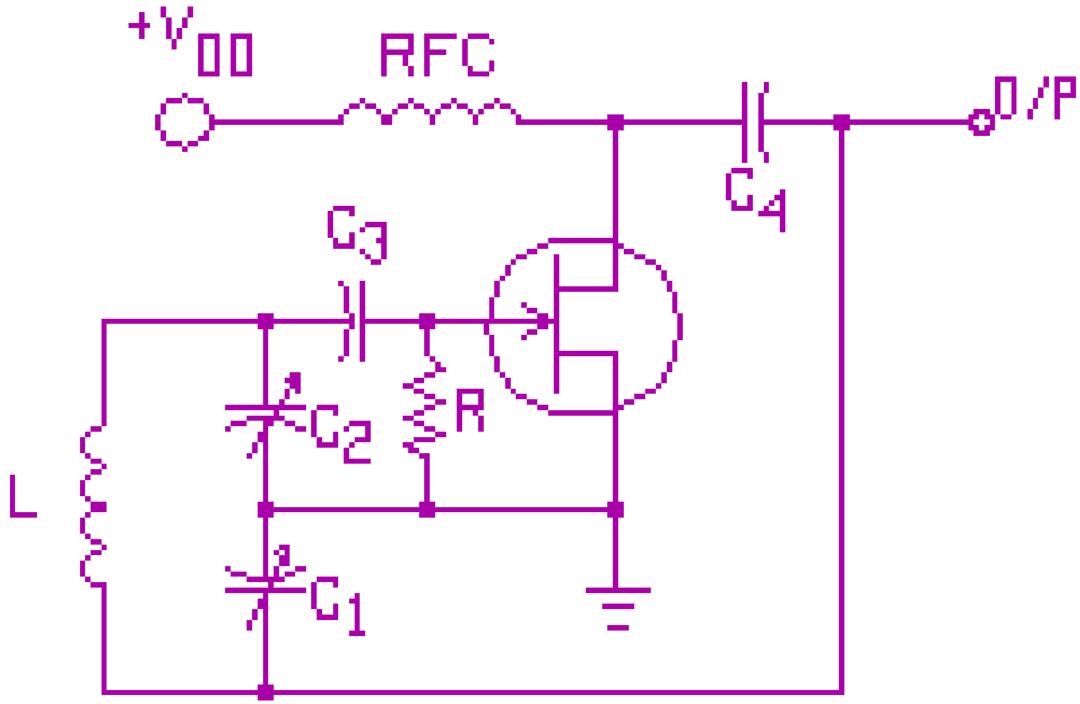


$$B = \frac{L_1 + L_2}{L_1}$$

$$f_o = \frac{1}{2\pi\sqrt{L_T C_1}};\ L_T = L_1 + L_2$$

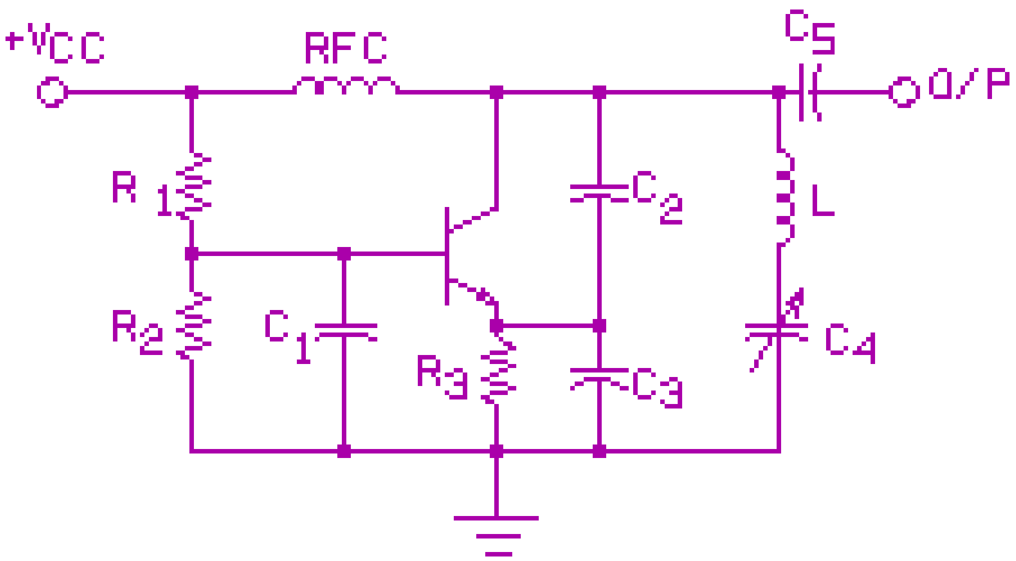
$$B = \frac{L_2}{L_1}$$

Colpitts Oscillator



$$B = \frac{C_1}{C_2}; \quad f_o = \frac{1}{2\pi\sqrt{LC_T}}; C_T = \frac{C_1 C_2}{C_1 + C_2}$$

Clapp Oscillator



$$B = \frac{C_2}{C_2 + C_3}; \; f_o = \frac{1}{2\pi\sqrt{LC_T}}$$

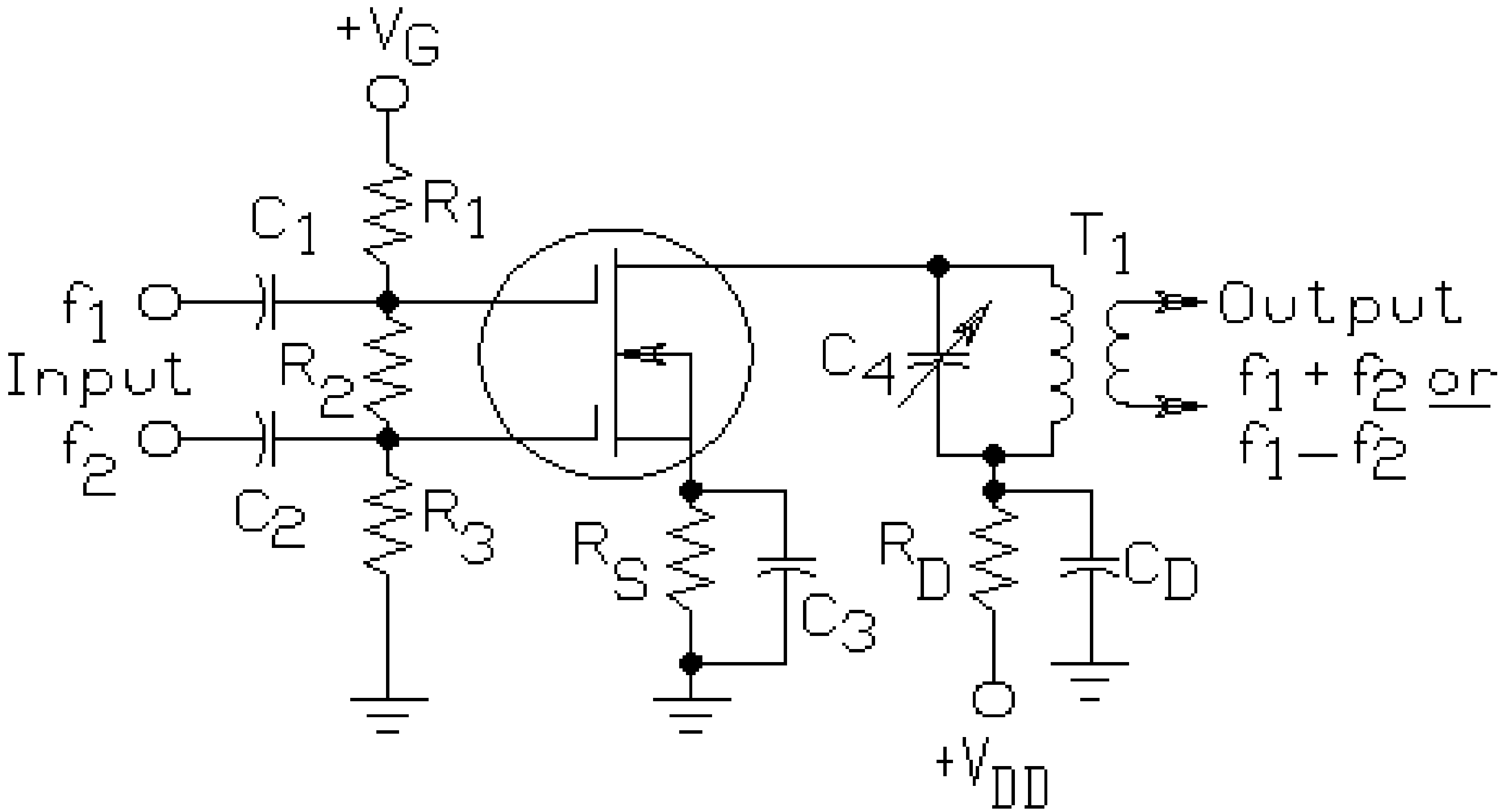
$$C_T = \frac{1}{\frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4}}$$

The Clapp oscillator is a variation of the Colpitts circuit. C_4 is added in series with L in the tank circuit. C_2 and C_3 are chosen large enough to "swamp" out the transistor's junction capacitances for greater stability. C_4 is often chosen to be << either C_2 or C_3, thus making C_4 the frequency determining element, since $C_T = C_4$.

Mixers

- A mixer is a nonlinear circuit that combines two signals in such a way as to produce the sum and difference of the two input frequencies at the output.
- A square-law mixer is the simplest type of mixer and is easily approximated by using a diode, or a transistor (bipolar, JFET, or MOSFET).

Dual-Gate MOSFET Mixer

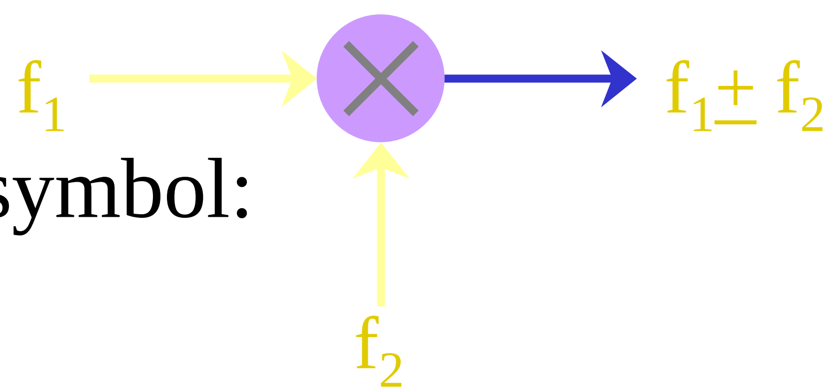


Good dynamic range and fewer unwanted o/p frequencies.

Balanced Mixers

- A balanced mixer is one in which the input frequencies do not appear at the output. Ideally, the only frequencies that are produced are the sum and difference of the input frequencies.

Circuit symbol:

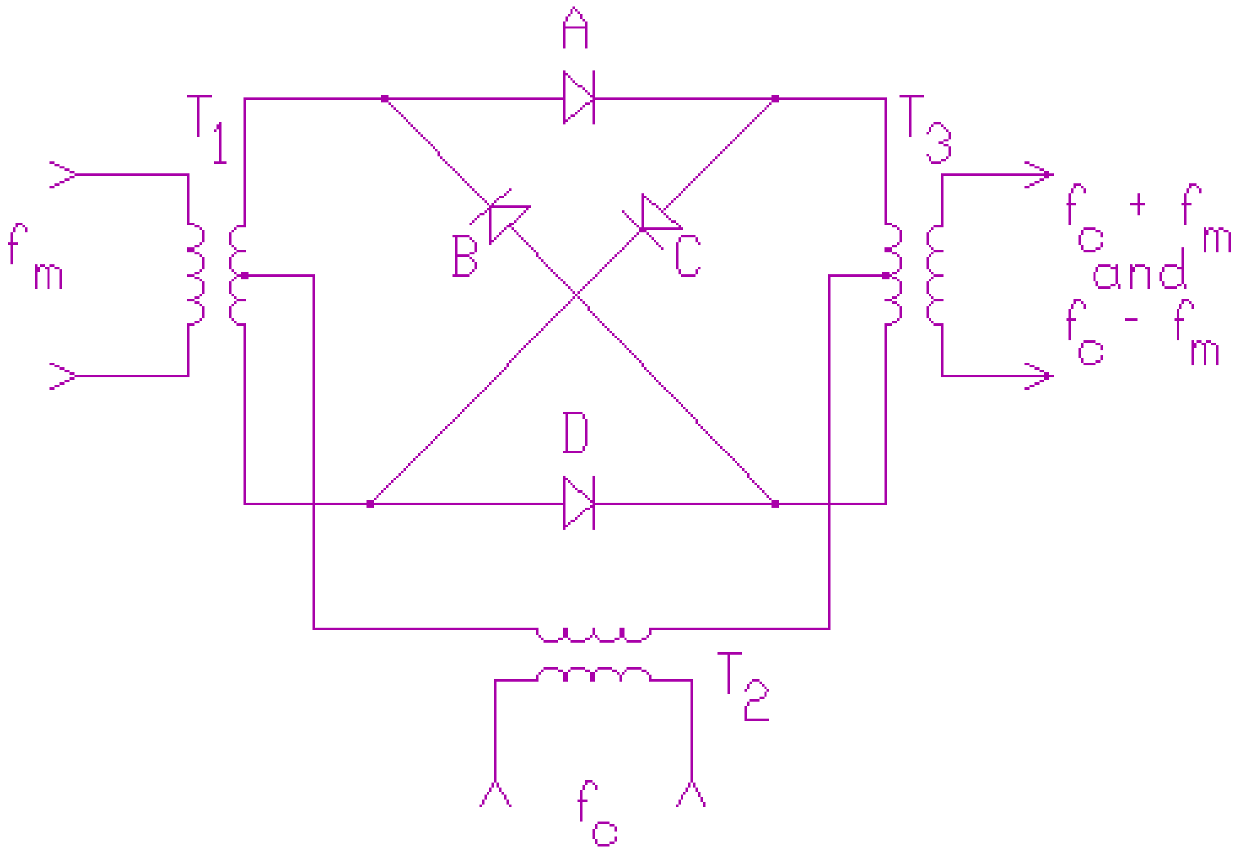


Equations for Balanced Mixer

Let the inputs be $v_1 = \sin \omega_1 t$ and $v_2 = \sin \omega_2 t$.
A balanced mixer acts like a multiplier. Thus
its output, $v_o = Av_1v_2 = A \sin \omega_1 t \sin \omega_2 t$.
Since $\sin X \sin Y = 1/2[\cos(X-Y) - \cos(X+Y)]$
Therefore, $v_o = A/2[\cos(\omega_1-\omega_2)t - \cos(\omega_1+\omega_2)t]$.

- The last equation shows that the output of the balanced mixer consists of the sum and difference of the input frequencies.

Balanced Ring Diode Mixer

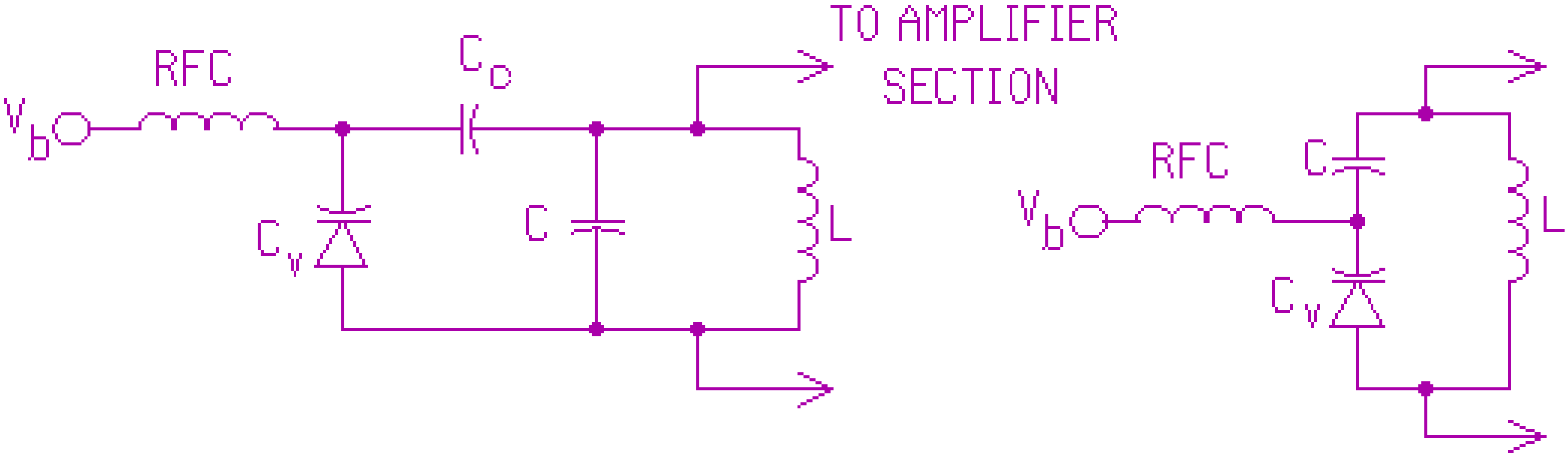


Balanced mixers are also called balanced modulators.

Voltage-Controlled Oscillator

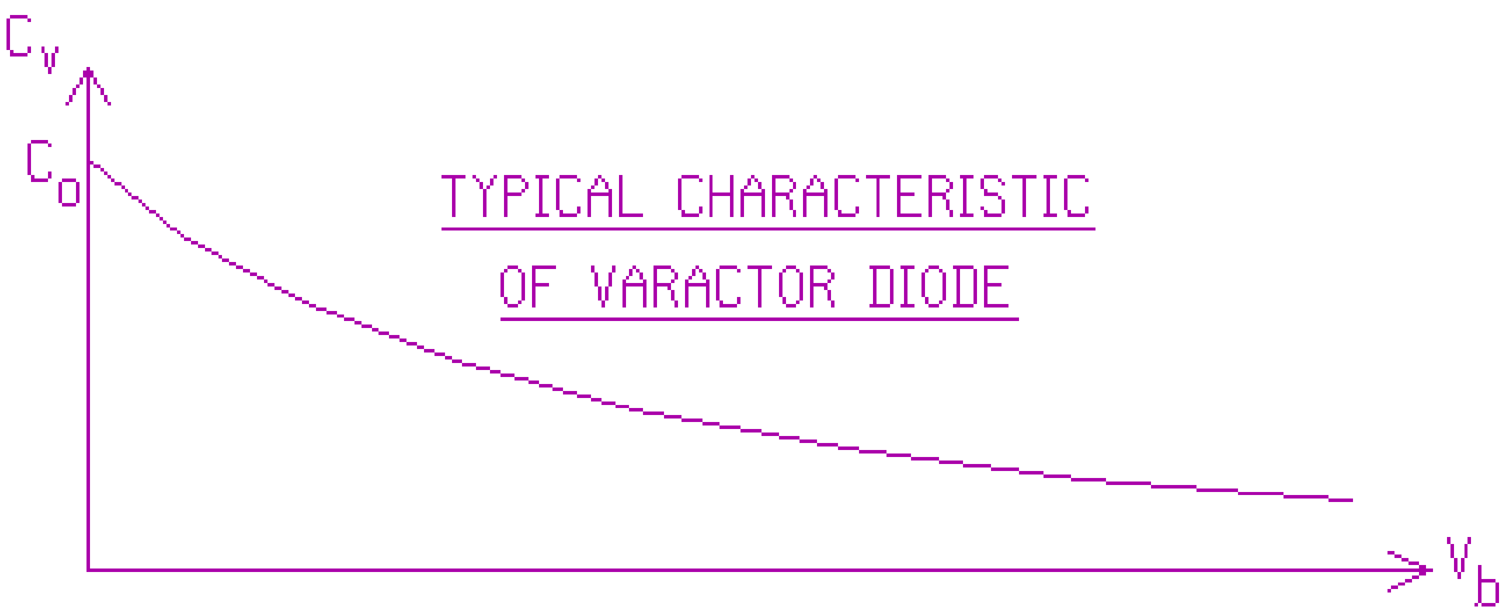
- VCOs are widely used in electronic circuits for AFC, PLL, frequency tuning, etc.
- The basic principle is to vary the capacitance of a varactor diode in a resonant circuit by applying a reverse-biased voltage across the diode whose capacitance is approximately:

$$C_V = \frac{C_o}{\sqrt{1+2V_b}}$$



(a) PARALLEL-CONNECTED (b) SERIES-CONNECTED

VCO CIRCUIT CONFIGURATIONS



TYPICAL CHARACTERISTIC OF VARACTOR DIODE