

Electronics of Radio (Supplement)

Notes on David Rutledge's book

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Modulation

- AM: $V(t) = a(t) \cos(\omega_c t) + V_c \cos(\omega_c t)$
- FM: $V(t) = V_c \cos([\omega_c + a(t)]t)$
- FSK: $V(t) = V_c \cos(\omega_1 t)$, if 1 [mark]; $V_c \cos(\omega_0 t)$, if 0 [space]
- PSK: $V(t) = V_p \cos(\omega_c t)$, if 1; $-V_p \cos(\omega_c t)$, if 0 [space]
- Gain: $G = \frac{P_o}{P_i}$, Loss: $L = \frac{P_o}{P_{max}}$, Rejection: $R = \frac{P_{max}}{P_{pb}}$,

Direct conversion receivers

- Mixer

- $V(t) = \cos(\omega_1 t) \cos(\omega_2 t) = \frac{1}{2} [\cos((\omega_1 + \omega_2)t) + \cos((\omega_1 - \omega_2)t)]$

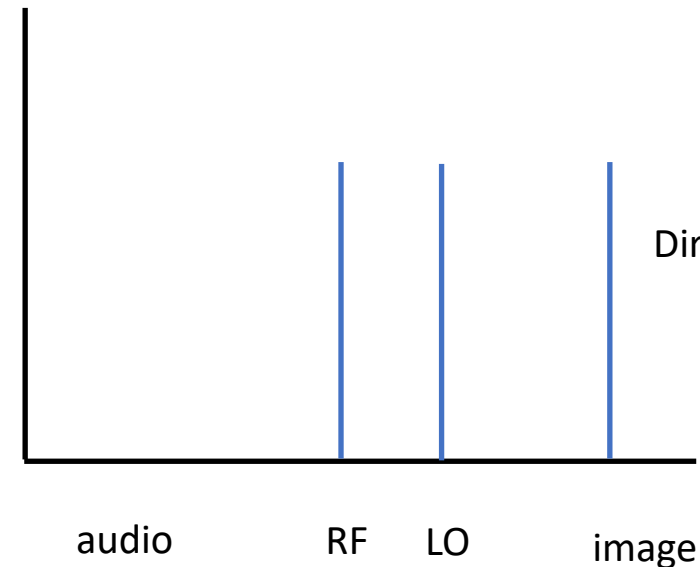
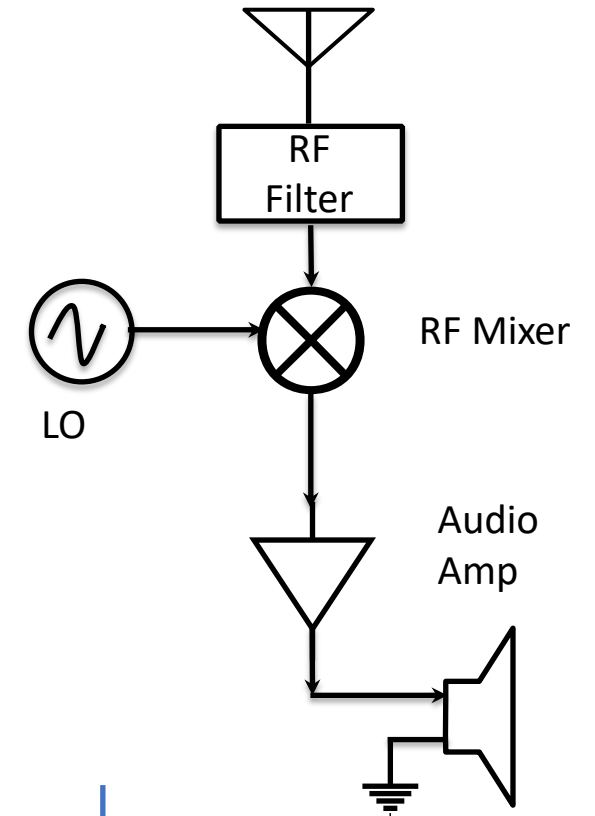
- Image frequency

- $\omega_{vi} = \omega_{LO} + \omega_a$
 - $\omega_{rf} = \omega_{LO} - \omega_a$

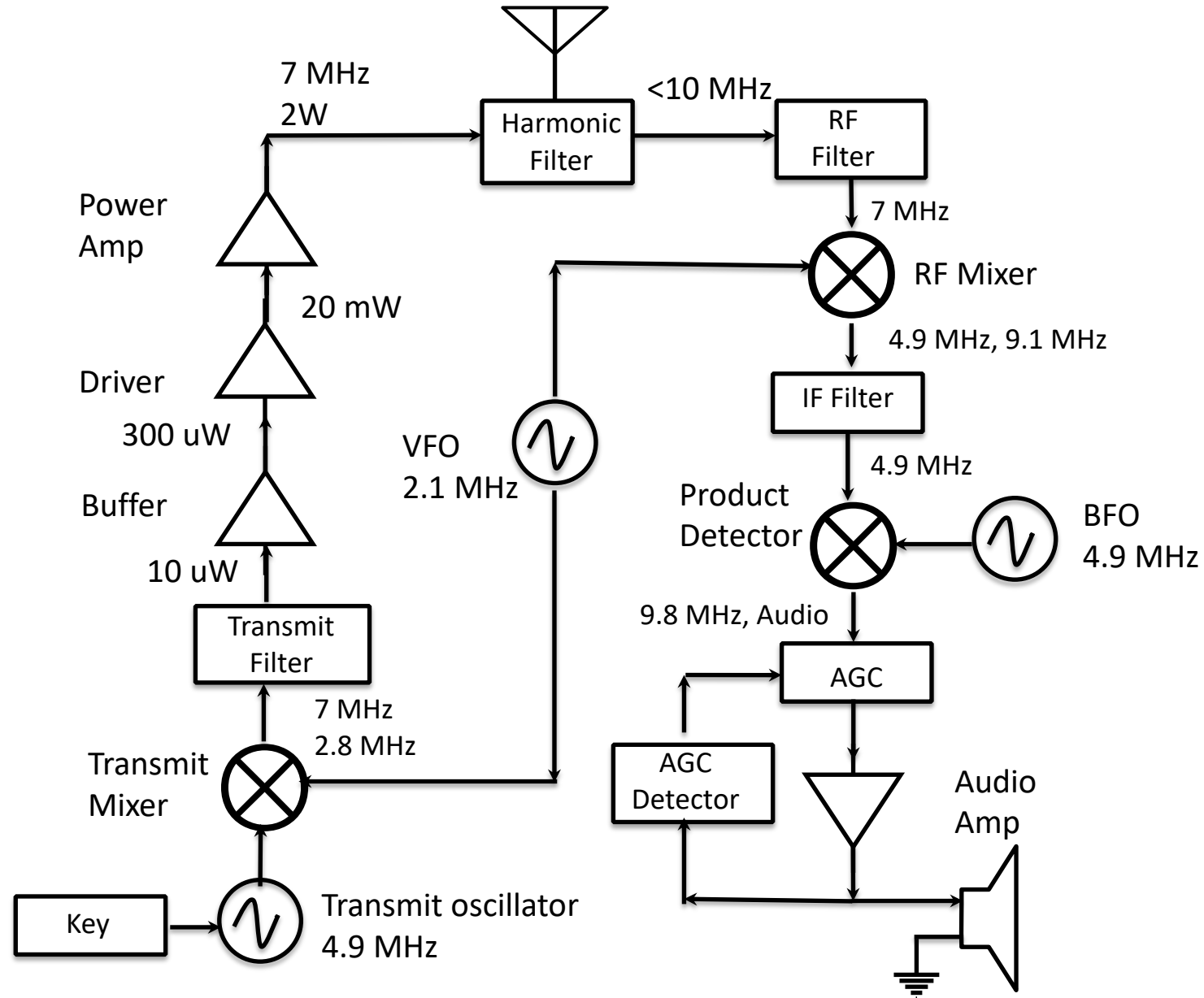
- RF filter removes image

- Downside:

- Not tunable

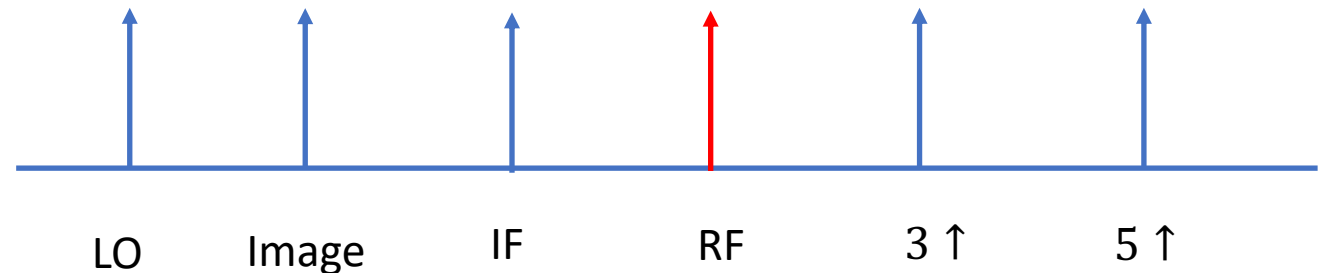


Norcal 40A



Mixers

- $V_{lo}(t)$ is a square wave with period ω_{lo} . Expanding this in a Fourier series, we get:
- $V_{lo}(t) = \frac{4}{\pi}(\cos(\omega_{lo}t) - \frac{\cos(3\omega_{lo}t)}{3} + \frac{\cos(5\omega_{lo}t)}{5} \dots)$, $V_{rf}(t) = V_{rf}\cos(\omega_{rf}t)$
- $V_{lo}(t)V_{rf}(t) = \frac{2V_{rf}}{\pi}(\cos(\omega_{-}t) - \frac{\cos(3\omega_{-}t)}{3} + \frac{\cos(5\omega_{-}t)}{5} \dots) + \frac{2V_{rf}}{\pi}(\cos(\omega_{+}t) - \frac{\cos(3\omega_{+}t)}{3} + \frac{\cos(5\omega_{+}t)}{5} \dots)$
- $\omega_{+} = \omega_{lo} + \omega_{rf}$ and $\omega_{-} = |\omega_{lo} - \omega_{rf}|$
- We define $\omega_{k+} = (k\omega_{lo} + \omega_{rf})$ and $\omega_{k-} = |k\omega_{lo} - \omega_{rf}|$ and $V_{k+}(t) = \frac{2V_{rf}}{k\pi}\cos(\omega_{k+}t)$ and $V_{k-}(t) = \frac{2V_{rf}}{k\pi}\cos(\omega_{k-}t)$
- $\omega_i = \omega_{if} - \omega_{lo}$ and $\omega_{if} = \omega_{if} + \omega_i$, ω_i is a spurious signal. ω_{k+} and ω_{k-} are the spurs from the k th harmonic



Phasors

- $V(t) = RI(t)$
- $V(t) = L\dot{I}(t)$
- $I(t) = C\dot{V}(t)$
- Suppose $V(t) = A\cos(\omega t + \theta)$ and $I(t) = B\cos(\omega t + \phi)$. If $\phi > \theta$, we say the current leads the voltage.
- $V(t) = \text{Re}(e^{j(\omega t + \theta)})$, and $I(t) = \text{Re}(e^{j(\omega t + \phi)})$
- Now define $V = Ae^{j\theta}$ and $I = Be^{j\phi}$, so $|V| = A$, $|I| = B$, $\angle V = \theta$, and $\angle I = \phi$. V and I are called phasors and do not include time. Note that $V(t) = \text{Re}(Ve^{j\omega t})$ and $I(t) = \text{Re}(Ie^{j\omega t})$.
- Note that $I = CVj\omega$, for a capacitor and $V = LIj\omega$, for an inductor
- $\hat{V} = Z\hat{I}$, $Z = R + jX$
- $\hat{I} = Y\hat{V}$, $Y = G + jB$

Series resonance and Q

- At ω_u and ω_l , $X = \pm R$ [ω_u is upper 3dB cutoff and ω_l is lower 3dB cutoff]
- $\omega_u L - \frac{1}{\omega_u C} = R$, $\omega_l L - \frac{1}{\omega_l C} = -R$
- Define $Q = \frac{X}{R}$
- $\frac{\omega_u}{\omega_0} - \frac{\omega_0}{\omega_u} = \frac{R}{\omega_0 L} = \frac{1}{Q}$ and $\frac{\omega_l}{\omega_0} - \frac{\omega_0}{\omega_l} = -\frac{R}{\omega_0 L} = -\frac{1}{Q}$
- $\frac{\omega_u}{\omega_0} - \frac{\omega_0}{\omega_u} = \frac{\omega_0}{\omega_l} - \frac{\omega_l}{\omega_0}$, so $\omega_0^2 = \omega_u \omega_l$ and $\frac{\omega_u - \omega_l}{\omega_0} = \frac{1}{Q}$

Parallel resonance and Q

- $\frac{\omega_u}{\omega_0} - \frac{\omega_0}{\omega_u} = \frac{G}{\omega_0 C} = \frac{1}{Q_p}$ and $\frac{\omega_l}{\omega_0} - \frac{\omega_0}{\omega_l} = -\frac{G}{\omega_0 C} = -\frac{1}{Q_p}$

Power

- $P(t) = I(t)V(t)$
- Complex power: $P = \frac{V\bar{I}}{2} = Z \frac{|I|^2}{2} = P_a + jP_r = R \frac{|I|^2}{2} + jX \frac{|I|^2}{2}$
 - P_a is power delivered to resistor, P_r is power stored in inductor and capacitor
- $P_r = \frac{\omega L |I|^2}{2} - \frac{\omega C |V_c|^2}{2} = \omega(E_L - E_C)$
- $Q = \omega \frac{L |I|^2}{R |I|^2} = \omega \frac{L}{R} = \omega \frac{E_L}{P_a}$

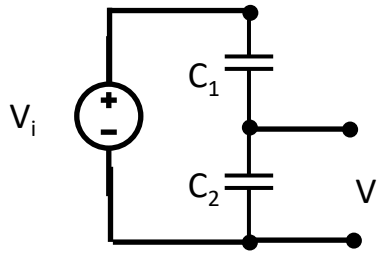
General formulas for Q

- x

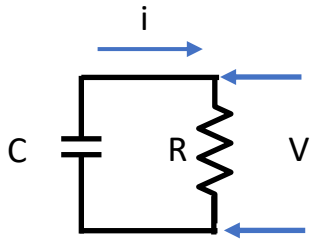
Exercises

- Calculate wave form through bridge and after “smoothing capacitor”

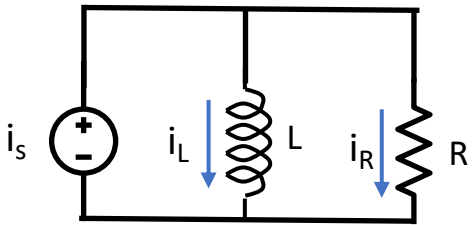
Misc-1



- $\frac{V}{V_i} = \frac{C_1}{C_1 + C_2}$



- $I = \frac{V}{R} = -CV', \tau = RC,$



- $\frac{L}{R} I_R' + I_R = 0$
- $i_s = i_r + i_L$

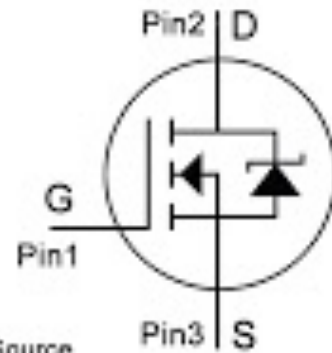
Pinouts

IRF510 MOSFET Pinout

TO-220 Package



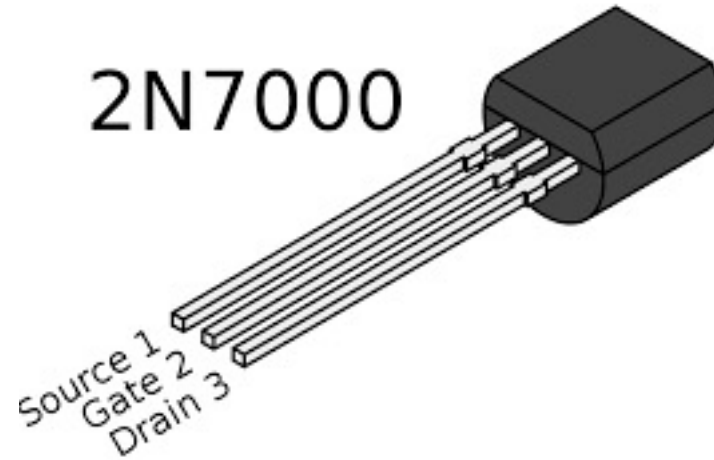
N Channel Mosfet



S = Source
G = Gate
D = Drain

www.componentsinfo.com
Electronics Components Uses, Features, Pinouts, Equivalents,
Applications & More...

2N7000

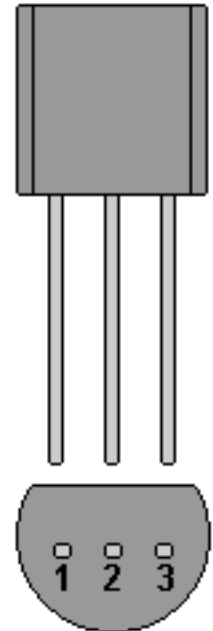


Source 1
Gate 2
Drain 3

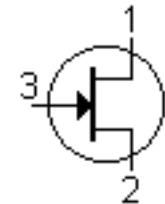


2N3904 pinout

1. Emitter
2. Base
3. Collector



1. DRAIN
2. SOURCE
3. GATE



JEDEC TO-92
J309

Blank