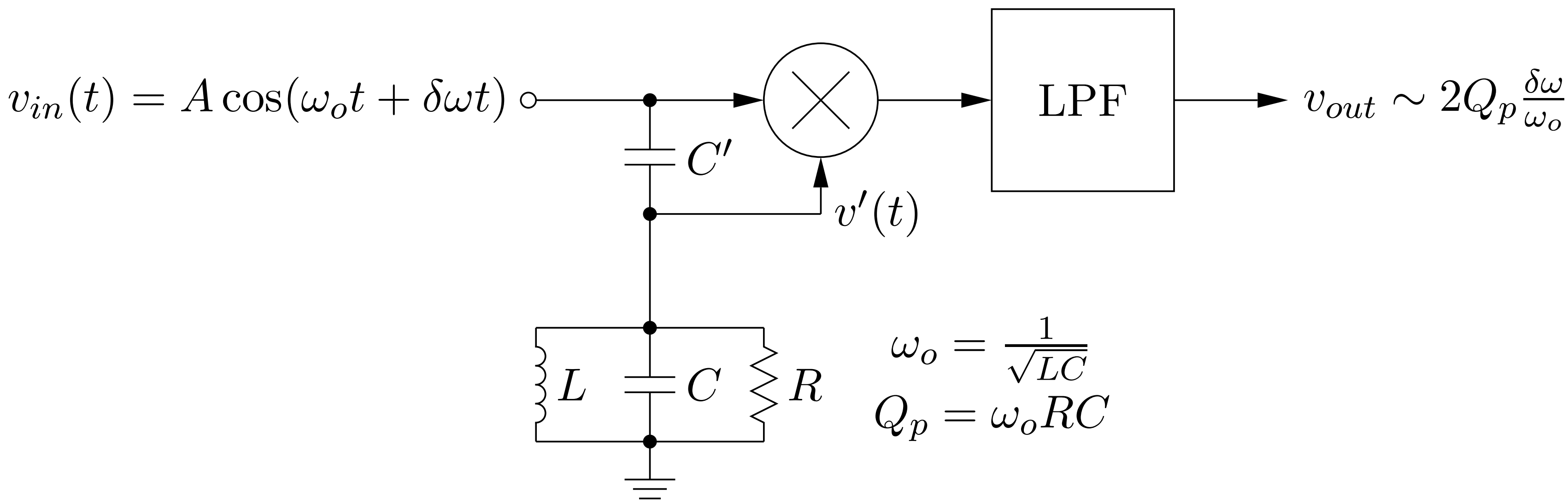
Quadrature FM Demodulator



• The demodulator operates with the RLC circuit tuned to resonance at the carrier frequency of v_{in}, ω_o.

• The voltage divider consisting of C' and the resonant RLC circuit converts small frequency deviations in v_{in} to phase shifts of v' relative to v_{in}.

• For small frequency deviations, $\delta\omega$, v' is phase shifted by $\pi/2 - 2Q_p\frac{\delta\omega}{\omega_o}$.

• The multiplier and LPF act as a phase comparator, producing output proportional to $2Q_p\frac{\delta\omega}{\omega_o}$ for small frequency deviations, $\delta\omega$.

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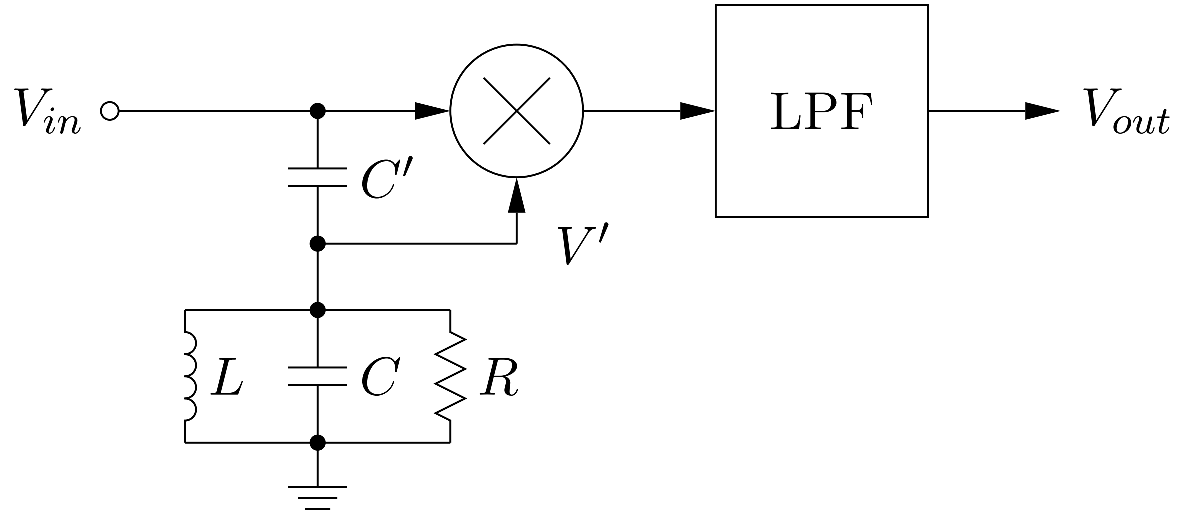


Using upper-case symbols V_{in}, V' for phasors:

$$V' = \frac{Z_p}{Z_p + \frac{1}{j\omega C'}} V_{in}; \qquad Z_p = j\omega L || \frac{1}{j\omega C} || R$$

If C' is small, such that $\frac{1}{\omega C'} \gg |Z_p|$, then $V' \simeq j\omega C' Z_p V_{in}$.

Let θ', θ_p, and θ_{in} represent the phase angles of V', Z_p, and V_{in}, respectively. Then:

$$\theta' = \frac{\pi}{2} + \theta_p + \theta_{in}$$

Phase difference between V_{in} and V' is $\frac{\pi}{2} + \theta_p$ where θ_p is the phase angle of Z_p.

Impedance of a parallel RLC circuit is:

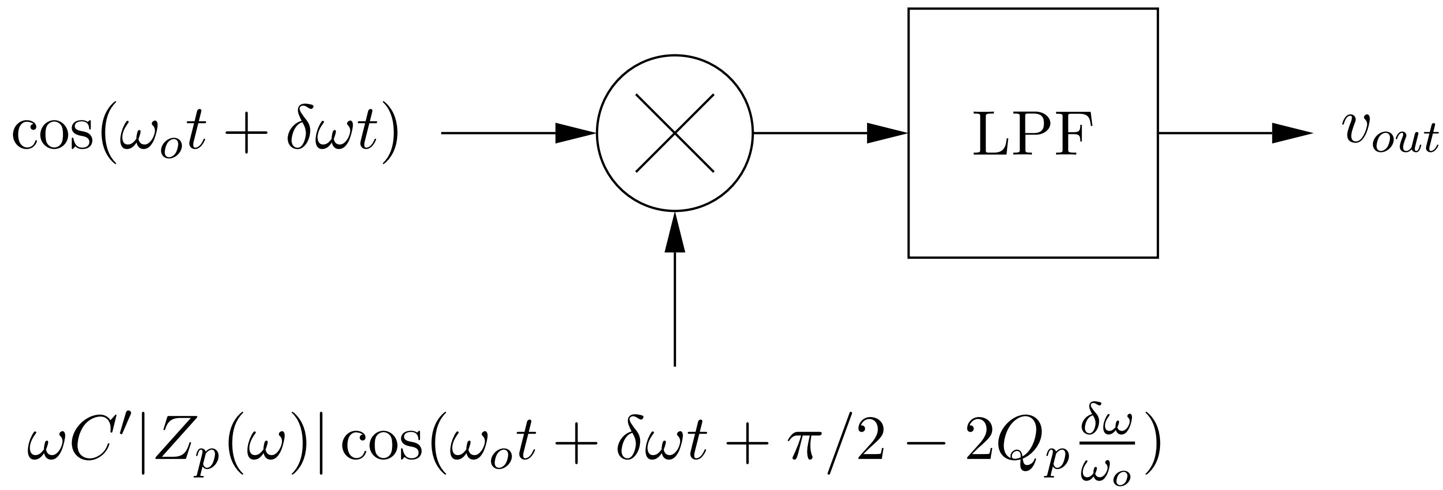
$$Z_p(\omega) = \frac{R}{1+jQ_p(\frac{\omega}{\omega_o}-\frac{\omega_o}{\omega})} = |Z_p(\omega)|e^{j\theta_p(\omega)}$$

$$\theta_p(\omega) = -\tan^{-1}Q_p(\frac{\omega}{\omega_o} - \frac{\omega_o}{\omega})$$

Let $\omega = \omega_o + \delta\omega$. If $\delta\omega \ll \omega_o$, then

$$\theta_p(\omega) \simeq -2Q_p\frac{\delta\omega}{\omega_o}$$

For small frequency deviations away from resonance the phase of Z_p is proportional to the frequency deviation, $\delta\omega$.



The multiplier is usually configured such that the lower input is "saturated", in which case the output does not depend on the magnitude of the lower input.

The lowpass filter rejects the double-frequency term in the mixer output, leaving the cosine of the phase difference. The output is:

$$v_{out} \sim \cos(\tfrac{\pi}{2} - 2Q_p \tfrac{\delta\omega}{\omega_o}) = \sin(2Q_p \tfrac{\delta\omega}{\omega_o})$$

If $2Q_p \frac{\delta\omega}{\omega_o} \ll 1$, then $v_{out} \sim 2Q_p \frac{\delta\omega}{\omega_o}$.

Summary:

- For small frequency deviations ($\delta\omega$) away from ω_o, $v_{out} \sim 2Q_p \frac{\delta\omega}{\omega_o}$.

- For large frequency deviations, the output is a nonlinear function of deviation. See section 4.5 of the course notes for details.

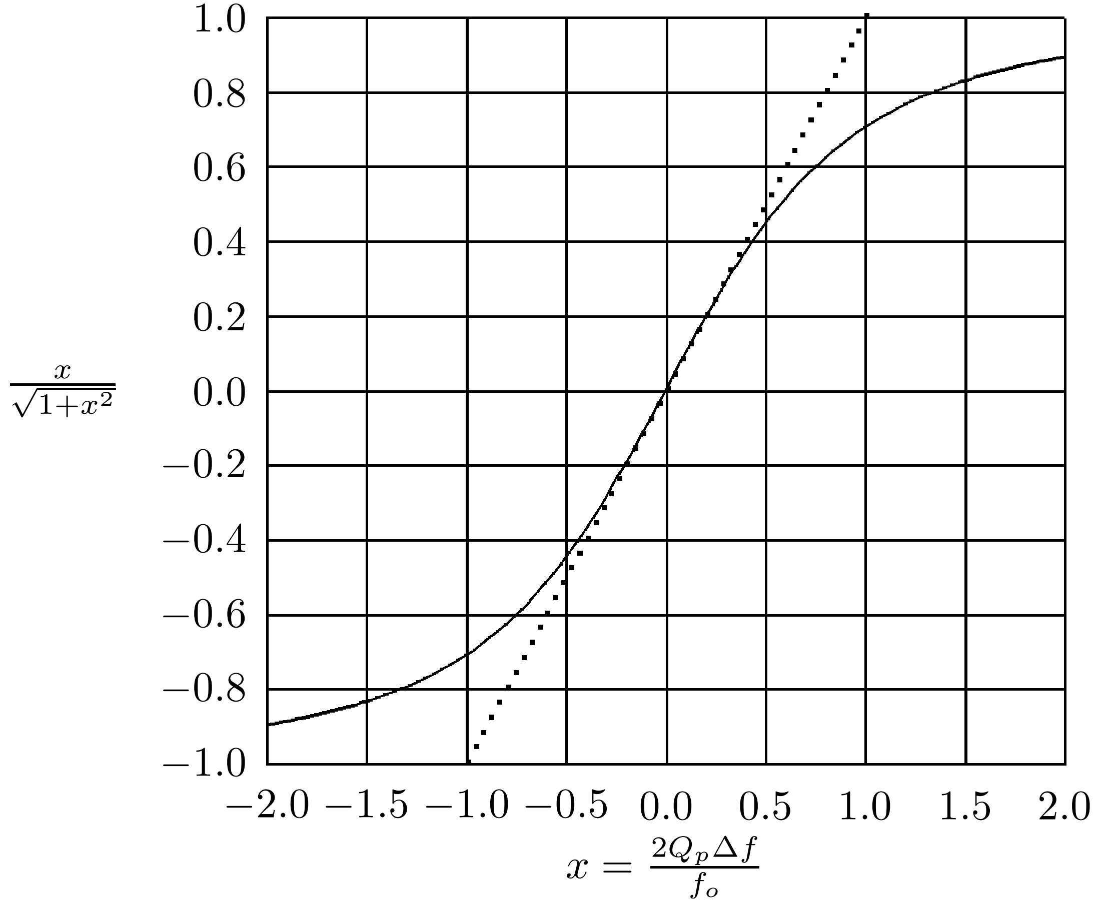


Figure 4.23: Output voltage verses normalized frequency deviation for a quadrature demodulator employing a saturated input for v'. The dotted line shows an ideal linear response with the same slope as the actual response at $x = 0$.