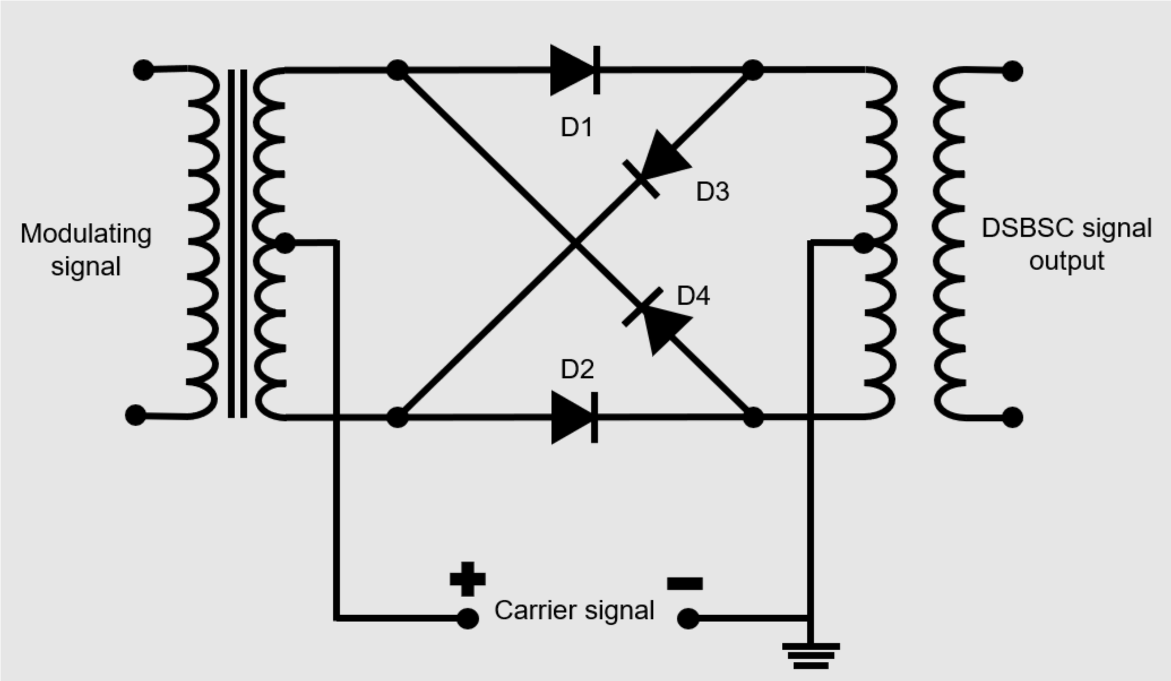
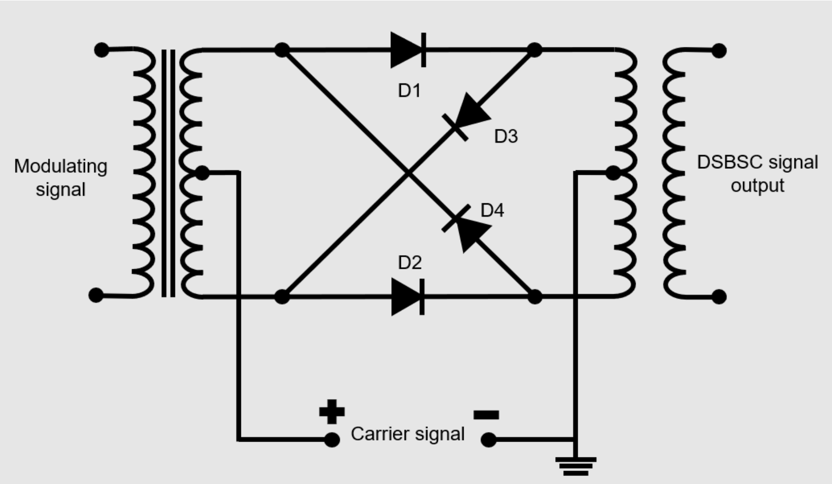
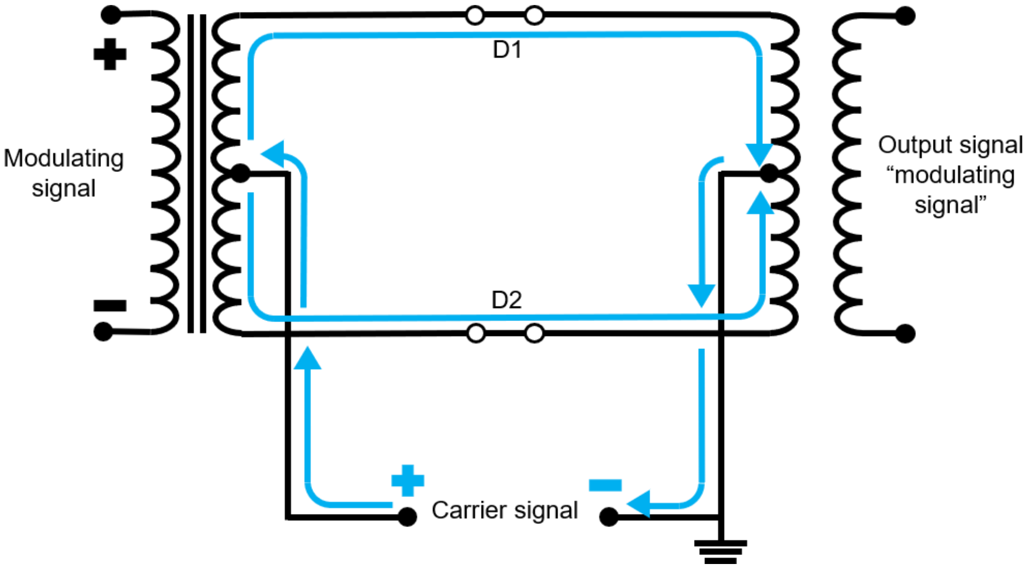
Ring Modulator

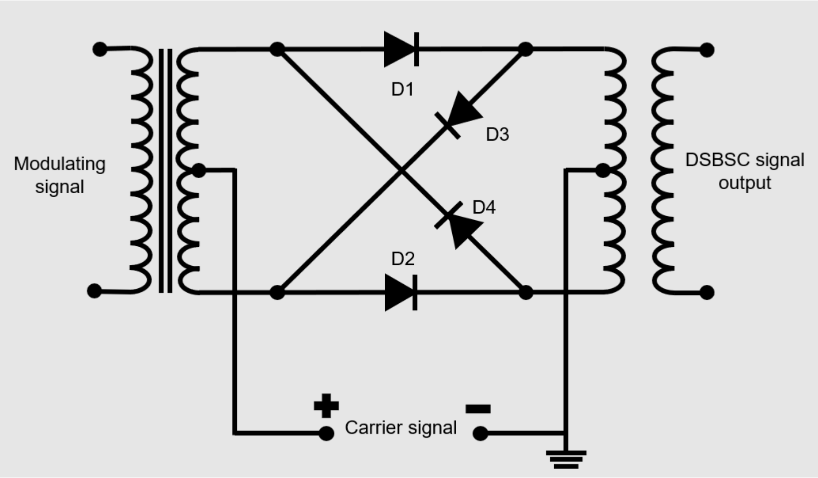


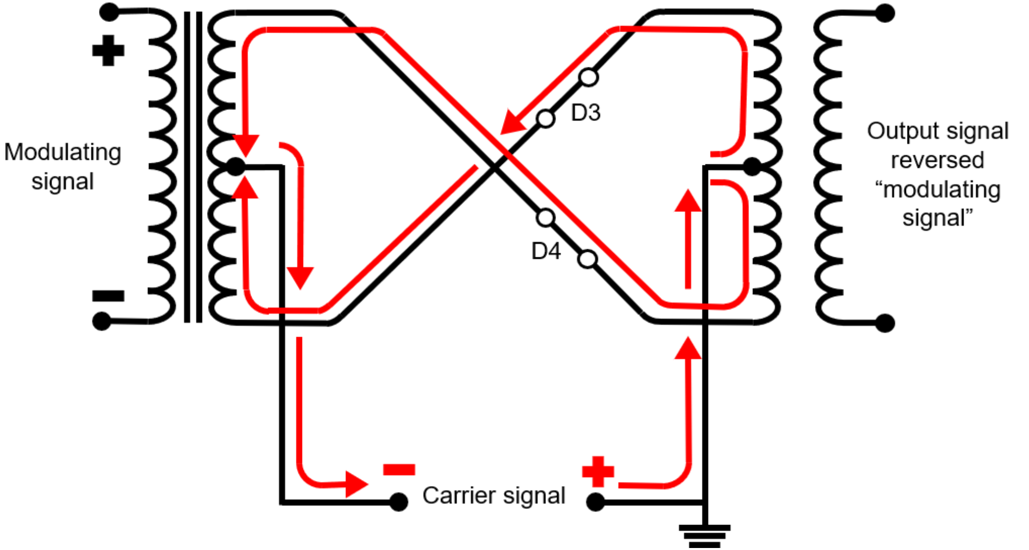
Positive Half-cycle Operation

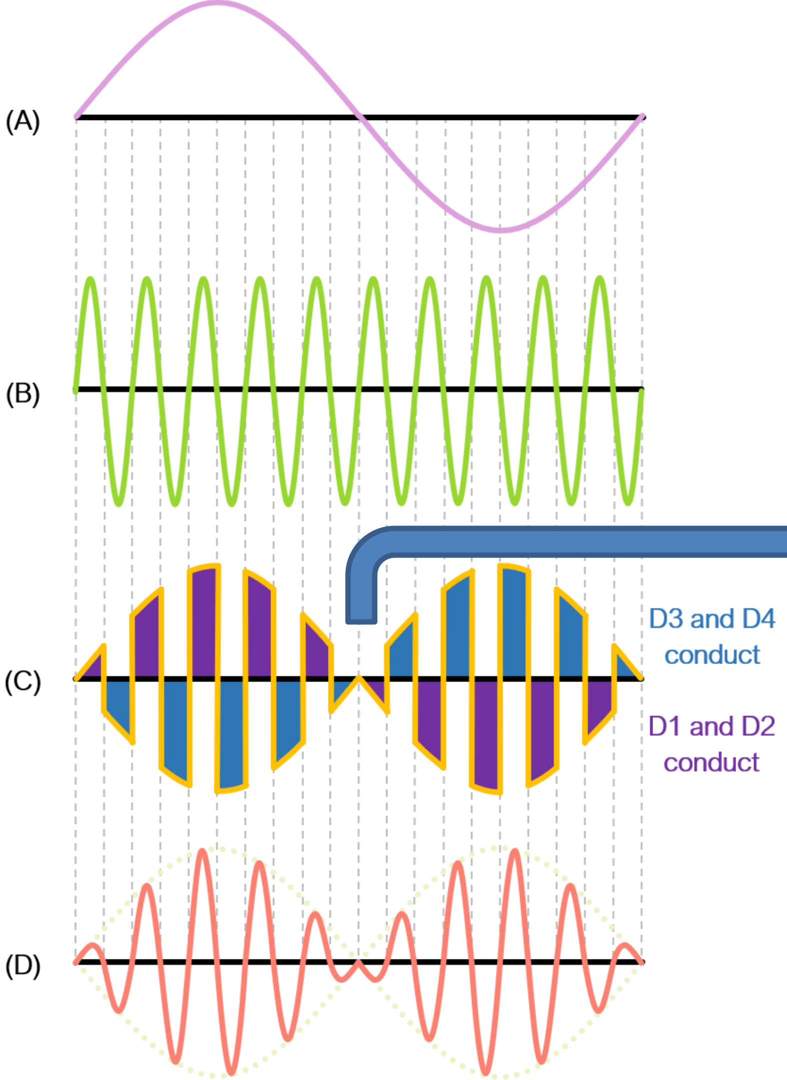




Negative Half-cycle Operation



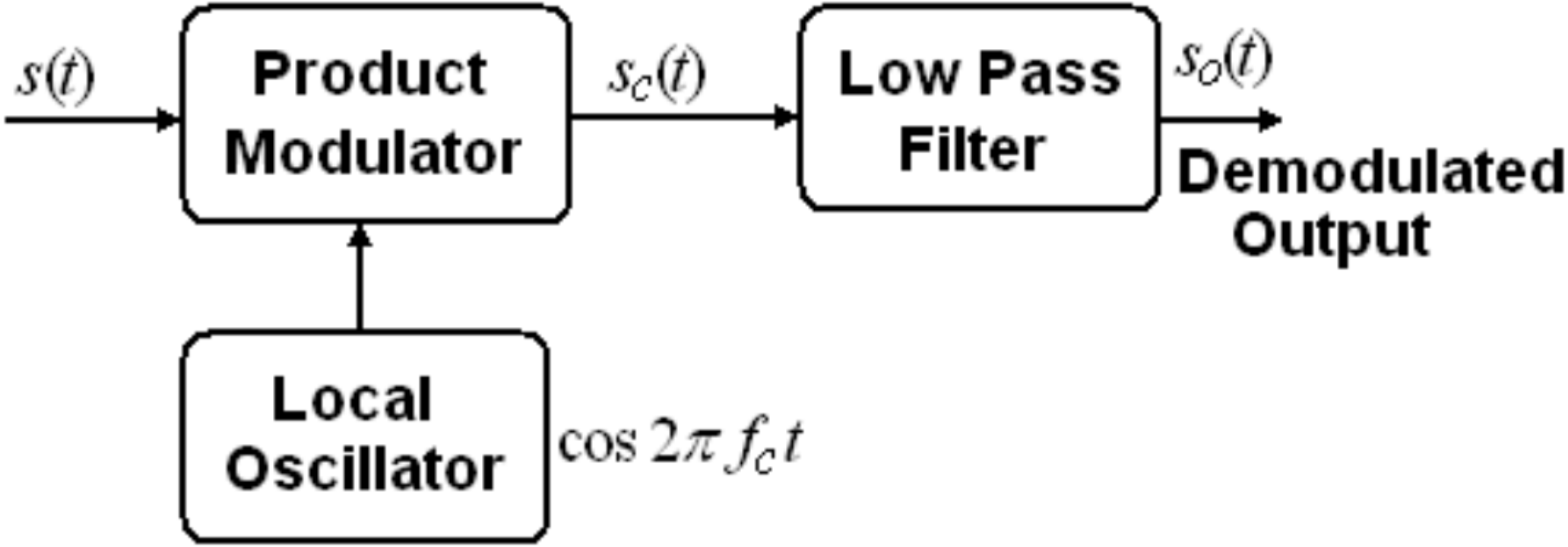




Phase reversal occurs at zero crossings

DSB-SC Demodulation

Coherent/Synchronous Detection



Coherent/Synchronous Detection

Let DSB-SC signal is $s(t) = A_c m(t) \cos 2\pi f_c t$.

Then the product modulator output $s_c(t)$ is given by

$$s_c(t) = s(t) \cos 2\pi f_c t = [A_c m(t) \cos 2\pi f_c t] \cos 2\pi f_c t$$

$$= A_c m(t) \cos^2 2\pi f_c t = A_c m(t) \frac{1}{2}[1 + \cos 4\pi f_c t]$$

Coherent/Synchronous Detection

$$= \frac{1}{2} A_c m(t) + \frac{1}{2} \cos 4\pi f_c t$$

After passing through the LPF we have

$$= \frac{1}{2} A_c m(t)$$

- Any discrepancy in the frequency and phase of local carrier give rise to a distortion in the detector output.

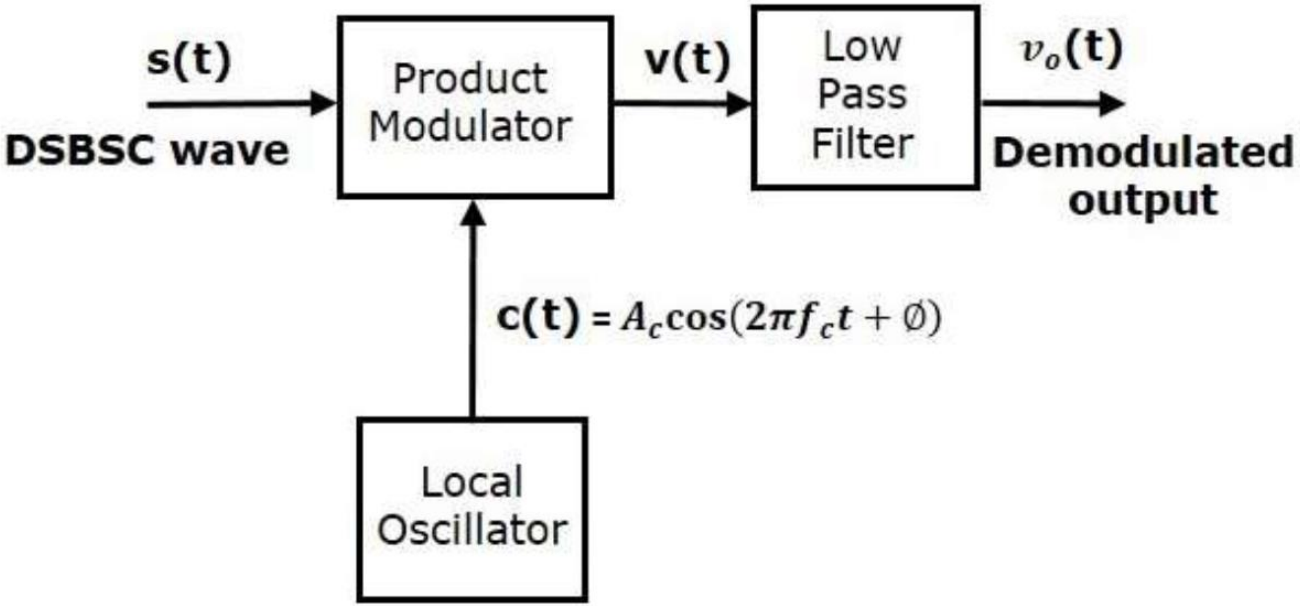
Consider the following two situations.

- The local oscillator has an ideal frequency, but arbitrary phase difference measured with respect to the carrier is referred to as '***Phase Error***'.

- The local oscillator has identical phase but a difference frequency with respect to carrier is referred to as '***Frequency error***'

Phase Error $\phi \neq 0; \Delta f = 0$

Let the carrier is $\cos(2\pi f_C t + \phi)$ where ϕ being the phase difference between the local oscillator signal and the carrier at the transmitter.



Phase Error $\phi \neq 0; \Delta f = 0$

Let the carrier is $\cos(2\pi f_C t + \phi)$ where ϕ being the phase difference between the local oscillator signal and the carrier at the transmitter.

$$s_C(t) = s(t)\cos(2\pi f_C t + \phi) = [A_C m(t)\cos 2\pi f_C t]\cos(2\pi f_C t + \phi)$$

$$= A_C \frac{1}{2} m(t)\left[\cos\phi + \cos(4\pi f_C t + \phi)\right]$$

$$= \boxed{\frac{1}{2} A_C m(t)\cos\phi} + \frac{1}{2} m(t)\cos(4\pi f_C t + \phi)$$

$$s_O(t) = \frac{1}{2} A_C m(t)\cos\phi$$

Phase Error

- Thus the demodulator output is proportional to $m(t)$ and undistorted when the phase error $\cos\phi$ is constant
- The demodulated output is maximum when $\phi = 0$
- Minimum (zero) when $\phi = \pm\frac{\pi}{2}$.

This results in distortion (Quadrature Null Effect) of the demodulated output .

Frequency Error $\phi = 0; \Delta f \neq 0$

Suppose that the local oscillator signal $\cos 2\pi(f_c + \Delta f)t$

where Δf is frequency error.

$$s_c(t) = s(t)\cos\{2\pi(f_c + \Delta f)t\} = [A_c m(t)\cos 2\pi f_c t]\cos\{2\pi(f_c + \Delta f)t\}$$

$$= A_c \frac{1}{2} m(t)\left[\cos 2\pi\Delta f t + \cos\{2\pi(2f_c + \Delta f)t\}\right]$$

$$= \frac{1}{2} A_c m(t)\cos 2\pi\Delta f t + \frac{1}{2} m(t)\cos\{2\pi(2f_c + \Delta f)t\}$$

$$s_o(t) = \frac{1}{2} A_c m(t)\cos 2\pi\Delta f t$$

The resulting signal will be un-acceptable if Δf is comparable to the baseband signal frequency

Conclusions

- Necessary arrangement should be made at the receiver end to maintain the local oscillator in perfect synchronism, in both frequency and phase with the transmitted carrier wave.

Limitations of AM and DSB-SC

Advantages of AM: Receiver design is simplified

Dis-advantages of AM:

1. Wastage of Carrier power
2. Wastage of Band width

Advantages of DSB-SC : Transmission efficiency improved. Carrier power is suppressed.

Dis-advantages of DSB-SC :

1. Wastage of Band width

SSB

- **Advantages:**
- More bandwidth efficient than DSB-SC. SSB requires bandwidth equivalent to message signal bandwidth.
- Carrier power and one sideband power saving.
- Reduced interference of noise, because of low bandwidth.

SSB

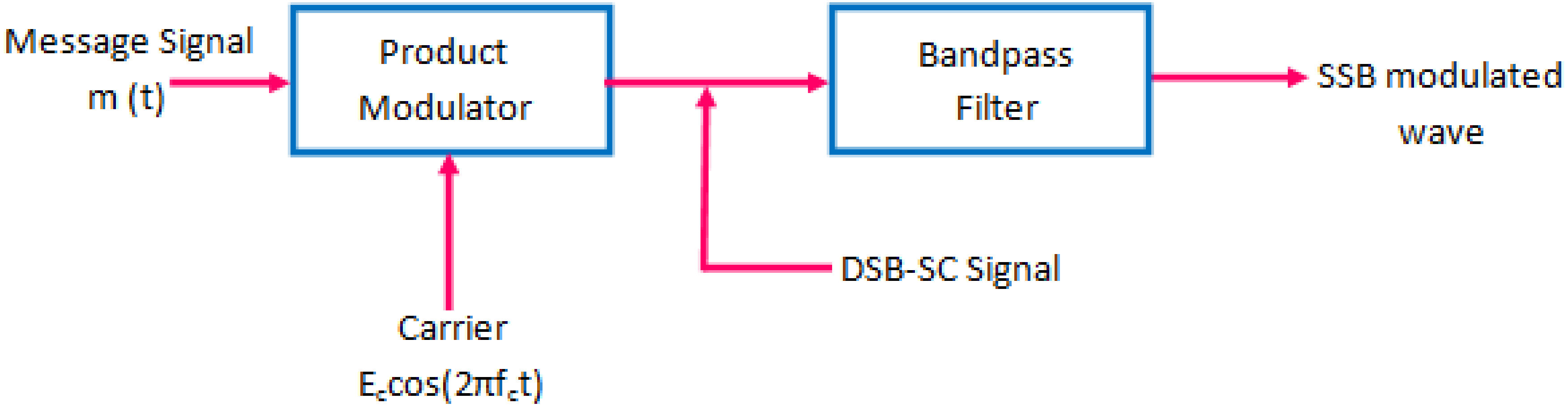
Disadvantages:

- Generation and reception is complicated.
- The SSB transmitter and receiver need to have excellent frequency stability. A slight change in frequency will distort both the transmitted and received signals. Therefore it is needed ideal filters in implementations.

SSB Generation

Frequency Discrimination Method/Filter Method

(By Adding Bandpass Filter at the output of DSB-SC generator)



Power & Power saving in SSB

Power in USB or LSB $P_T'' = \frac{1}{4} m_a^2 P_c$

$$\text{Power saving with respect to AM with carrier} = \frac{P_T - P_T''}{P_T}$$

$$\text{Power saving with respect to AM with carrier} = \frac{P_{\mathrm{T}} - P_{\mathrm{T}}''}{P_{\mathrm{T}}}$$

$$= \frac{\left[1 + \frac{m_{\mathrm{a}}^2}{2}\right] P_{\mathrm{C}} - \left[\frac{m_{\mathrm{a}}^2}{4} \cdot P_{\mathrm{C}}\right]}{\left[1 + \frac{m_{\mathrm{a}}^2}{2}\right] P_{\mathrm{C}}}$$

$$= \frac{P_{\mathrm{C}} + \frac{m_{\mathrm{a}}^2}{2} P_{\mathrm{C}} - \frac{m_{\mathrm{a}}^2}{4} P_{\mathrm{C}}}{\left[1 + \frac{m_{\mathrm{a}}^2}{2}\right] P_{\mathrm{C}}} = \frac{\left[1 + \frac{m_{\mathrm{a}}^2}{4}\right]}{\left[1 + \frac{m_{\mathrm{a}}^2}{2}\right]}$$

$$= \frac{4 + \dfrac{m_a^2}{4}}{2 + \dfrac{m_a^2}{2}}$$

$$= \frac{4 + m_a^2}{4 + 2\,m_a^2}$$

For $m_a = 1$,

$$\%\ \text{power saving} = \frac{5}{6} \times 100 = 83.3\%$$