

We can integrate the wave *only* during the positive cycle. The integral will be different for different wave shapes. We can use this value to distinguish between different wave shapes. Consider three wave shapes with the same peak to peak voltage and frequency, all with an average value of 0 V. ( $t = 0$  at the positive zero crossing of the input signal).

Sinusoidal:  $v(t) = V_0 \sin 2\pi ft$ .

Square:  $v(t) = V_0$  for  $t \leq T/2$ , and  $v(t) = -V_0$  for  $t > T/2$

Triangular:

$$\begin{aligned} v(t) &= V_0 \alpha t \text{ for } 0 \leq t < T/4, \text{ with } \alpha = 4/T \\ v(t) &= V_0(2 - \alpha t) \text{ for } T/4 \leq t < 3T/4 \\ v(t) &= -V_0(4 - \alpha t) \text{ for } 3T/4 \leq t < T \end{aligned}$$

Integral of the three over the positive half cycle is given by:

$$\begin{aligned} I_1 &= \int_0^{T/2} V_0 \sin 2\pi f t dt = -\frac{V_0}{2\pi f} \cos 2\pi f t \Big|_0^{T/2} = \frac{V_0}{\pi f} = \frac{V_0 T}{\pi} \\ I_2 &= \int_0^{T/2} V_0 dt = \frac{V_0 T}{2} \\ I_3 &= V_0 \left( \int_0^{T/4} \alpha t dt + \int_{T/4}^{T/2} (2 - \alpha t) dt \right) = V_0 \left( \frac{\alpha}{2} t^2 \Big|_0^{T/4} + (2t - \alpha t^2/2) \Big|_{T/4}^{T/2} \right) \\ &= V_0 \left( \frac{2}{T} \frac{T^2}{16} + 2 \left( \frac{T}{2} - \frac{T}{4} \right) - \frac{2}{T} \left( \frac{T^2}{4} - \frac{T^2}{16} \right) \right) \\ &= V_0 T \left( \frac{1}{8} + \frac{1}{2} - \frac{3}{8} \right) = \frac{V_0 T}{4} \end{aligned}$$

(We could have shown that  $I_3 = I_2/2$  geometrically)!

To generate timing for integration, we can convert the input to a square wave using a comparator and use it to generate timing information to integrate only during the positive half cycle. (The integrator will be reset during the negative cycle).

Peak detection of the integrator output will give us a DC value which will be proportional to  $V_0 T / \pi$ ,  $V_0 T / 2$  or  $V_0 T / 4$ . However, this is dependent on  $V_0 T$ . To take care of this, one can find the peak value of the input and integrate this DC value from 0 to  $T/2$  to get  $V_0 T / 2$ . This can be scaled to get thresholds which can be given to 2 comparators. By determining in which range the integral of positive half of the input lies, we can determine the wave shapes.

Note that if an inverting integrator is used, we can integrate during the negative half and reset during the positive half to get the same effect.

Also, a precision rectifier followed by a low pass filter should also produce outputs proportional to  $I_1$ ,  $I_2$  and  $I_3$ . Check that out. (A precision rectifier is an opamp amplifier with a diode in the feedback path). Search the internet for a detailed circuit.

– Block Diagram Overleaf.

