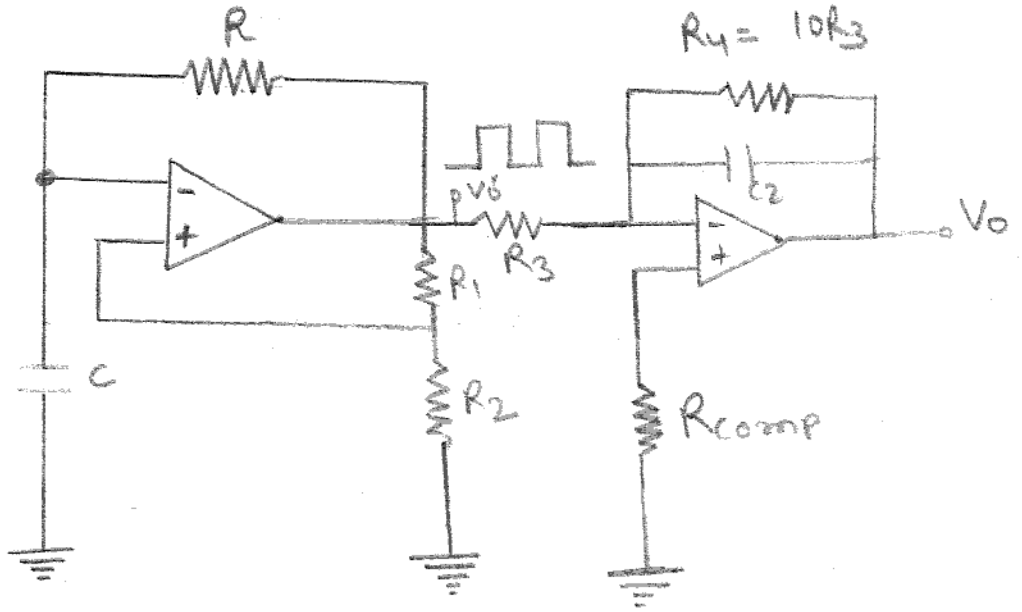
Triangular Wave Generator

A triangular wave can be simply obtained by integrating a square as shown in fig(a). It is obvious that the square wave and triangular wave is the same in fig(b). Although the amplitude of the square wave is constant at ± Vsat the amplitude of the triangular wave will decrease as the frequency increases. This is because the reactance of the capacitor C_2 in the feedback circuit decreases at high frequencies. A resistance R_4 is connected across C_2 to avoid the saturation problem at low frequencies as in the case of practical integrator.



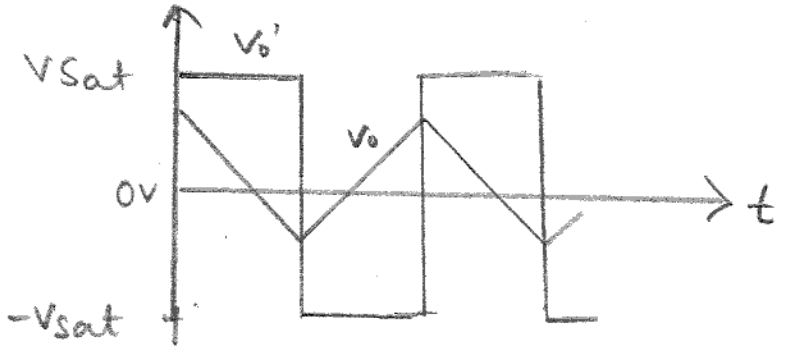
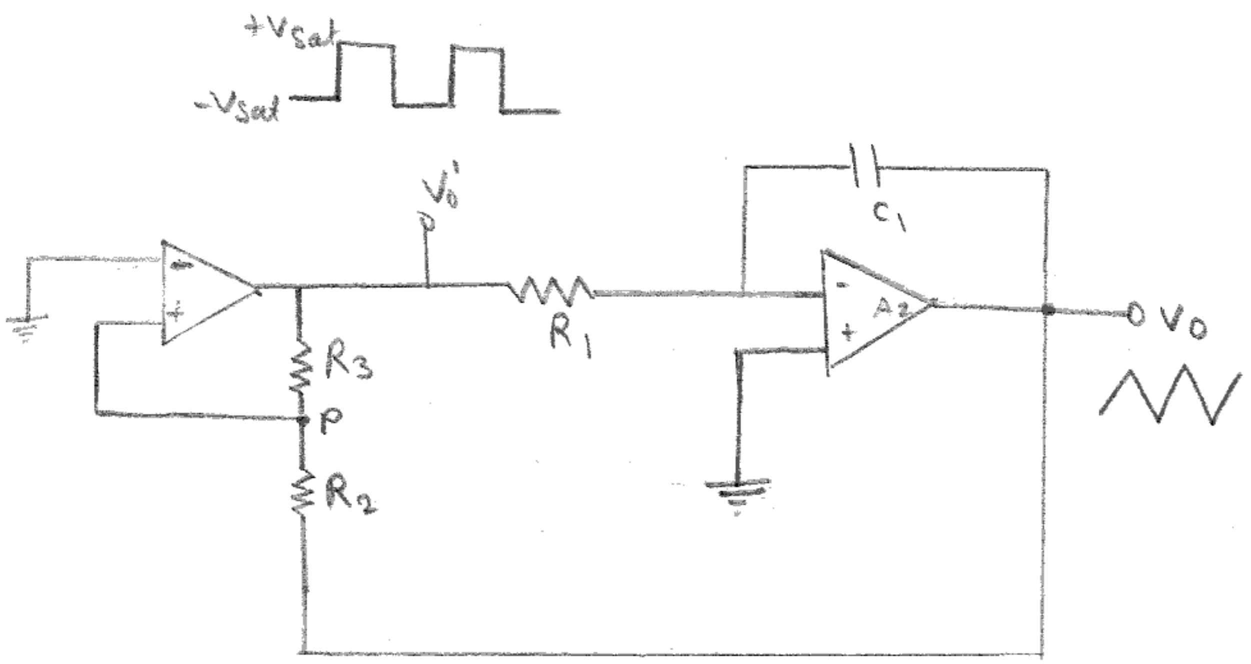


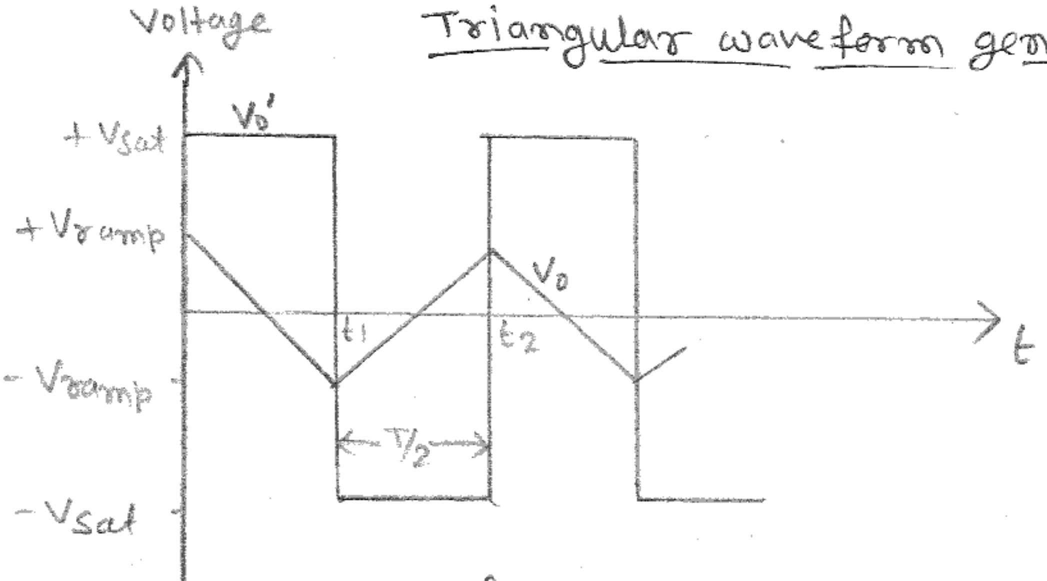
fig (b) output waveform

Another triangular wave generator using lesser number of components is show in above fig. It basically consists of a two level comparator followed by an integrater. The output of comparator A_1 is a square wave of amplitude $\pm$ Vsat and is applied to the (-) input terminal of the integrator A_2 Producing a triangular wave. This triangular wave is fed back as input to the comparater A_1 through a voltage divider R_2R_3.

initially, let us consider that the output of comparator A_1 is at +Vsat. The output of the integrator A_2 will be a negative going ramp as shown in fig. Thus one end of the voltage divider R_2R_3 is at a voltage +Vsat and the other at the negative going ramp of A_2. At a time $t = t_1$, when the negative going ramp attains a value of $-V_{ramp}$ the effective voltage at point P becomes slightly less than 0V. This switches the output of A_1 from positive saturation to negative saturation level -Vsat. During the time when the output of A_1 is at $-V_{sat}$, the output of A_2 increases in the positive direction. And at the instant $t=t_2$, the output of A_2· voltage at point P becomes just above 0V, thereby switching the output of A_1 from $-V_{sat}$ to $+V_{sat}$. The cycle repeats and generates a triangular waveform.



Triangular waveform generator.



waveforms

The effective voltage at point p during the time when output of A_1 is at $+V_{sat}$ level is given by

$$-V_{ramp} + \frac{R_2}{R_2+R_3}[+V_{sat} - (-V_{ramp})] \quad \text{---} (1)$$

At $t = t_1$, the voltage at point p becomes equal to zero, There fore

$$-V_{ramp} = -\frac{R_2}{R_3}(+V_{sat}) \quad \text{---} (2)$$

Similarly at $t = t_2$ when the output of A_1 switches from $-V_{sat}$ to V_{sat};

$$V_{ramp} = -\frac{R_2}{R_3}(-V_{sat})$$

$$= \frac{R_2}{R_3}(V_{sat}) \quad \text{---} (3)$$

Therefore peak to peak amplitude of the triangular wave is

$$V_o(PP) = +V_{ramp} - (-V_{ramp})$$

$$= \frac{2R_2}{R_3} V_{sat} \quad \text{---} (4)$$

The output switches from $-V_{ramp}$ to $+V_{ramp}$ in half the time period $T/2$ putting the values in the basic integrater equation

$$V_o = -\frac{1}{RC}\int V_i dt$$

$$V_o(PP) = -\frac{1}{R_1C_1}\int_0^{T/2}(-V_{sat})dt$$

$$= \frac{V_{sat}}{R_1C_1}\left(\frac{T}{2}\right)$$

$$\Rightarrow T = 2R_1C_1\frac{V_o(PP)}{V_{sat}} \quad \text{---} (5)$$

Putting the value of $V_o(PP)$ from eq. (4)

$$T = \frac{4R_1C_1R_2}{R_3}$$

Hence the frequency of oscillation f_o is

$$\boxed{f_o = \frac{1}{T} = \frac{R_3}{4R_1R_2C_1}}$$

⟨2⟩ LOG AMPLIFIER AND ANTILOG AMPLIFER

There are several applications of log and antilog amplifier. Antilog computation may require functions such as ln x, log x or sinh x. These can be performed continuously with log-amps. One would like to have direct dB display on digital voltmeter and spectrum analyser. Log-amp can be easily perform this function. Log-amp can also used to compress the dynamic range of a signal

LOG AMPLIFIER

The fundamental log-amp circuit in Fig. (a) where a grounded base transistor is placed in the feedback path. since the collector is held at virtual ground and the base is also grounded the transistor's voltage-current relationship becomes that of a diode and is given by.

$$I_E = I_S\left(e^{qV_E/KT} - 1\right) \quad \text{—— (1)}$$

since $I_C = I_B$ for a grounded base transistor.

$$I_C = I_S\left(e^{qV_E/KT} - 1\right) \quad \text{—— (2)}$$

I_S = emitter saturation current $\simeq 10^{-13}$ A

K = Boltzman's constant

T = absolute temperature (in °K)

Therefore $$\frac{I_C}{I_S} = \left(e^{qV_E/KT} - 1\right) \quad \text{—— (3)}$$

or $$e^{qV_E/KT} = \frac{I_C}{I_S} + 1$$

$$\simeq \frac{I_C}{I_S} \quad \left[\text{as } I_S \simeq 10^{-13}A,\ I_C \gg I_S\right]$$

Taking natural log on both sides, we get

$$V_E = \frac{KT}{q} \ln\left(\frac{I_C}{I_S}\right) \quad \text{—— (4)}$$

$$\because I_C = \frac{V_1}{R_1}$$

$$V_E = -V_o$$

So, $$V_o = -\frac{KT}{q} \ln\left(\frac{V_1}{R_1 I_s}\right) = -\frac{KT}{q} \ln\left(\frac{V_i}{V_{ref}}\right)$$

where. $V_{ref} = R_1 I_s$

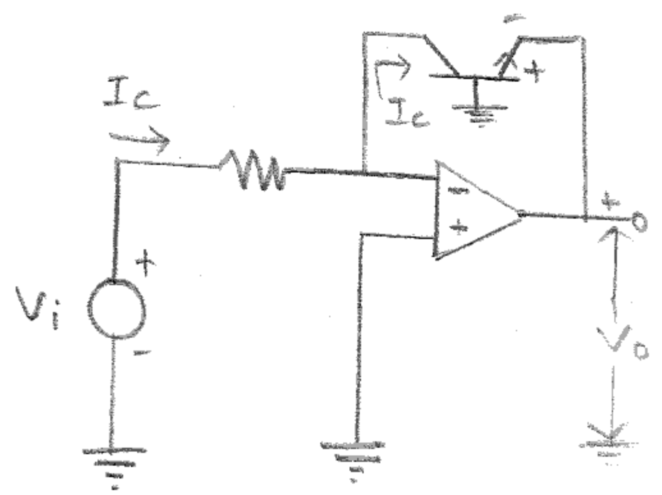


Fig. (a) Fundamental log-amp circuit.

The output voltage is thus proportional to the logarithm of input voltage. Although the ckt gives natural log (ln). one can find $\log_{10}$ by proper scaling.

$$\log_{10} X = 0.4343 \ln X$$

The circuit, however, has one problem. The emitter saturation current I_s varies from transister ~~to~~ transister and with temperature. Thus a stable reference voltage V_{ref} cannot be obtained. This is eliminated by the ckt given in Fig. 4.18(b). The input is applied to one log-amp, while a refernce voltage is applied to another log-amp. The two transistors are integrated close together in the same silicon wafer. This provides a close match of saturation currents and ensures good thermal tracking.

Assume $I_{S1} = I_{S2} = I_S$

and then

$$V_1 = \frac{KT}{q} \ln\left(\frac{V}{R_1 I_S}\right)$$

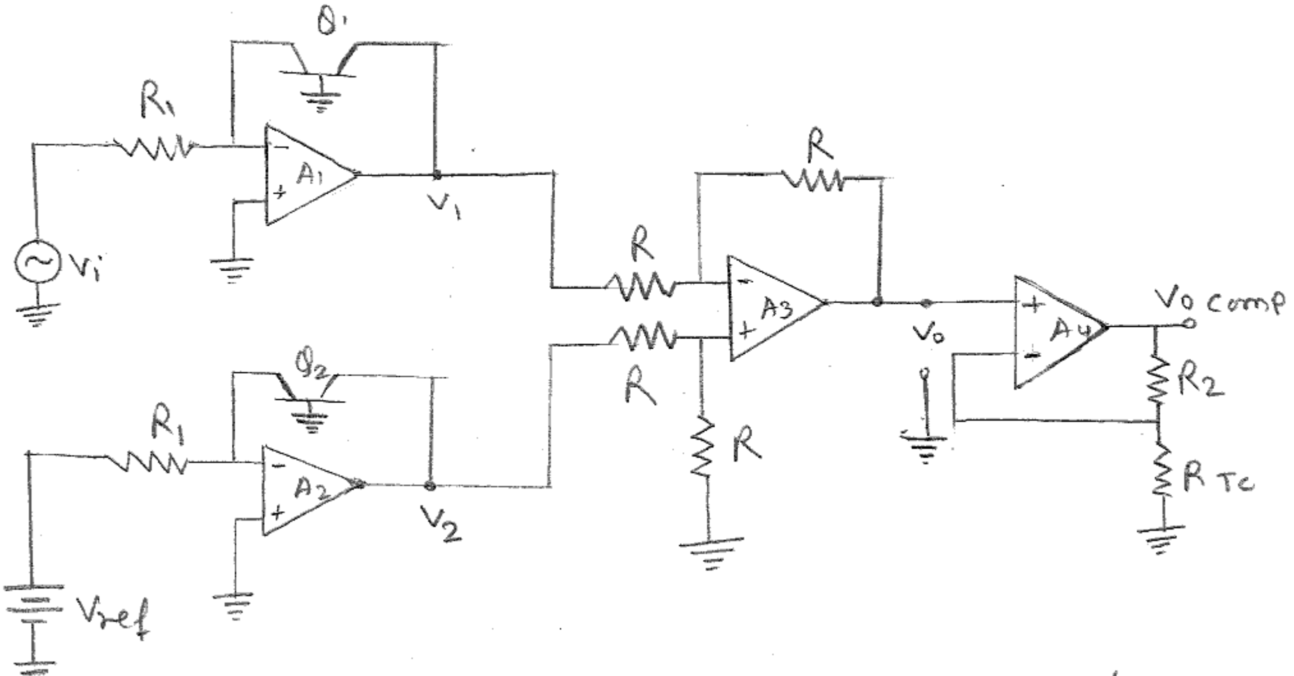


Fig. Log-amp with saturation current and temparature compensation.

and $$V_2 = -\frac{KT}{q} \ln\left(\frac{V_{ref}}{R_1 I_S}\right)$$

$$V_o = V_2 - V_1 = \frac{KT}{q}\left[\ln\left(\frac{V_i}{R_1 I_S}\right) - \ln\left(\frac{V_{ref}}{R_1 I_S}\right)\right]$$

$$\boxed{V_o = \frac{KT}{q} \ln\left(\frac{V_i}{V_{ref}}\right)}$$

Antilog Amplifier

In this ckt the input V_i for the antilog. amp is fed into the temperature compensating voltage divider R_2 and R_{TC} and then to the base of Q_2. The output V_o of the antilog. amp is fed back to the inverting into of A_1 through the resister R_1. The base to emitter voltage of transisters Q_1 and Q_2 can be written as

$$V_{Q_1\,B-E} = \frac{kT}{q} \ln\left(\frac{V_o}{R_1 I_s}\right)$$

and $$V_{Q_2\,B-E} = \frac{kT}{q} \ln\left(\frac{V_{ref}}{R_1 I_s}\right)$$

Since the base of Q_1 is tied to ground we get

$$V_A = -V_{Q_1 B-E} = -\frac{kT}{q} \ln\left(\frac{V_o}{I_s R_1}\right)$$

the base voltage V_B of Q_2 is

$$V_B = \left(\frac{R_{TC}}{R_2 + R_{TC}}\right) V_i$$

The voltage at the emitter of Q_2 is

$$V_{Q_2 E} = V_B + V_{Q_2 \cancel{B}-B}$$

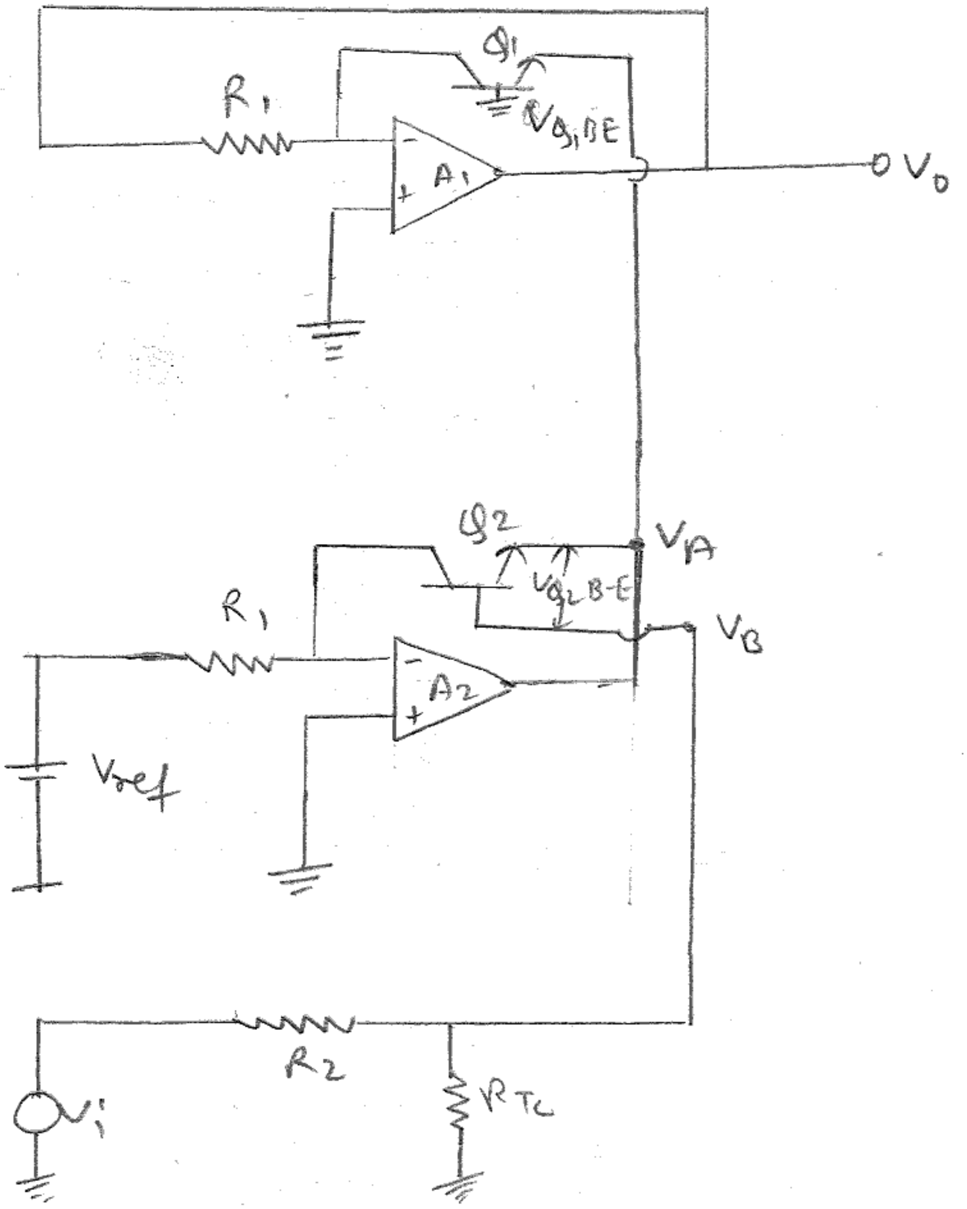
or

$$V_{Q_2 E} = \left(\frac{R_{TC}}{R_2 + R_{TC}}\right) V_i - \frac{kT}{q} \ln\left(\frac{V_{ref}}{R_1 I_s}\right)$$

But the emitter voltage of Q_2 is V_A that is

$$V_A = V_{Q_2E}$$

$$-\frac{KT}{q} \ln \frac{V_o}{R_1 I_s} = \frac{R_{TC}}{R_2 + R_{TC}} V_i - \frac{KT}{q} \ln \frac{V_{ref}}{R_1 I_s}$$



ANITLOG AMP.

$$\Rightarrow \quad \frac{R_{TC}}{R_2 + R_{TC}} V_i = -\frac{KT}{q}\left(\ln \frac{V_o}{R_1 I_s} - \ln \frac{V_{ref}}{R_1 I_s}\right)$$

$$= \quad -\frac{q}{KT} \cdot \frac{R_{TC}}{R_2 + R_{TC}} V_i = \ln\left(\frac{V_o}{V_{ref}}\right)$$

changing natural log, i-e ln to $\log_{10}$ ~~using~~

$$-0.4343\left(\frac{q}{KT}\right)\left(\frac{R_{TC}}{R_2+R_{TC}}\right)V_i = 0.4343 \times \ln\left(\frac{V_o}{V_{ref}}\right)$$

$$-K'V_i = \log_{10}\left(\frac{V_o}{V_{ref}}\right)$$

or $$\frac{V_o}{V_{ref}} = 10^{-K'V_i}$$

$$\boxed{V_o = V_{ref}\left(10^{-K'V_i}\right)}$$

where $K' = 0.4343\left(\frac{q}{KT}\right)\left(\frac{R_{TC}}{R_2+R_{TC}}\right)$