RC phase shift Osc:

Freq of Oscillation

\[ V_0(s) - V_1(s) \]
\[ \frac{1}{sC} = \frac{V_1(s)}{R} + \frac{V_1(s) - V_2(s)}{sC} \]
\[ \frac{V_0(s) - V_1(s)}{sC} = \frac{V_1(s)}{R} + sC \left( V_1(s) - V_2(s) \right) \]
\[ \frac{V_0(s) - V_1(s)}{R} = V_1(s) + sCR \left( V_1(s) - V_2(s) \right) \]
\[ \frac{V_0(s) - sCR V_1(s)}{R} = V_1(s) + sCR V_1(s) - sCR V_2(s) \]
\[ \frac{1}{sC} = \frac{V_1(s) + sCR V_1(s) + sCR V_2(s)}{1 + 2sCR} \]

\[ V_1(s) = \frac{V_0(s) + V_2(s)}{1 + 2sCR} \]
At node $V_2(s)$

$I_3(s) = I_4(s) + I_5(s)$

$$\frac{V_1(s) - V_2(s)}{V_A} = \frac{V_2(s)}{V_A} + \frac{V_2(s) - V_0(s)}{V_A}$$

$$R_C \left[ V_1(s) - V_2(s) \right] = \frac{V_2(s)}{R} + R_C \left[ V_2(s) - V_0(s) \right]$$

$$R_C \left[ V_1(s) - V_2(s) \right] = \frac{V_2(s)}{R} + R_C \left[ V_2(s) - V_0(s) \right]$$

$$R_C V_1(s) = R_C V_2(s) + V_2(s) + R_C V_2(s) - R_C V_0(s)$$

$$R_C V_1(s) = V_2(s) \left[ 1 + 2R_C \right] - R_C V_0(s)$$

$$V_1(s) = \frac{1 + 2R_C}{R} V_2(s) - V_0(s)$$

$$V_1(s) = \frac{1 + 2R_C}{R} V_2(s) - V_0(s) - \Theta$$

At node $V_0(s)$; $I_5(s) = I_6(s)$

$$\frac{V_2(s) - V_0(s)}{V_A} = \frac{V_0(s)}{A}$$

$$R_C \left[ V_2(s) - V_0(s) \right] = \frac{V_0(s)}{R}$$

$$R_C \left[ V_2(s) - V_0(s) \right] = \frac{V_0(s)}{R}$$
\[
\begin{align*}
V_2(s) &= \frac{1 + sCR}{sCR} V_I(s) + V_I(s) \\
\Rightarrow V_2(s) &= \frac{1 + sCR}{sCR} V_I(s) - 3 \\
\text{Sub eqn.} 3 \text{ in eqn.} 2 \text{ we get} \\
V_1(s) &= \frac{2sCR + 1}{sCR} \left[ \frac{1 + sCR}{sCR} \right] V_I(s) - V_I(s) - 4 \\
\text{From eqn. } 1 \text{ we get} \\
V_1(s) &= \frac{[V_I(s) + V_2(s)]sCR}{1 + sCR} \\
\text{Sub in eqn.} 4 \text{ we get} \\
\frac{V_0(s) \cdot sCR}{1 + sCR} + \frac{V_2(s) \cdot sCR}{1 + sCR} + V_I(s) &= \frac{2sCR + 1}{sCR} \left[ \frac{1 + sCR}{sCR} \right] V_I(s) - V_I(s) - 4 \\
\text{From eqn. } 3 \text{ we get} \\
\frac{sCRV_0(s)}{1 + sCR} + \left( \frac{1 + sCR}{sCR} \right) V_I(s) \cdot \frac{1 + sCR}{sCR} + V_I(s) &= \frac{2sCR + 1}{sCR} \left[ \frac{1 + sCR}{sCR} \right] V_I(s) - V_I(s) - 4 \\
\frac{sCRV_0(s)}{1 + sCR} + \left[ \frac{1 + sCR}{1 + sCR} \right] V_I(s) &= \frac{1 + sCR}{sCR} \left[ \frac{1 + sCR}{1 + sCR} \right] V_I(s) - V_I(s) - 4 \\
\frac{V_0(s)}{1 + sCR} + V_I(s) \left( \frac{1 + sCR}{1 + sCR} \right) V_I(s) &= \frac{1 + sCR}{sCR} \left[ \frac{1 + sCR}{1 + sCR} \right] V_I(s) - V_I(s) - 4 \\
\frac{V_0(s)}{1 + sCR} + V_I(s) \left( \frac{1 + sCR}{1 + sCR} \right) V_I(s) &= \frac{1 + sCR}{sCR} \left[ \frac{1 + sCR}{1 + sCR} \right] V_I(s) - V_I(s) - 4 \\
\end{align*}
\]
\[ \frac{\Delta V}{V_0(a)} = \frac{\sum \left[ 1 + 3\alpha C R + 2\alpha^2 c^2 R^2 \right] V_y(b)}{\Delta^2 c^2 R^2} \left( \frac{\left[ 1 + 3\alpha C R + 2\alpha^2 c^2 R^2 \right] V_y(b)}{\Delta^2 c^2 R^2} \right) V_y(b) \]

\[ \frac{\Delta c^3 R^3}{\Delta V_0(b)} = \frac{\left( \sum \left[ 1 + 3\alpha C R + 2\alpha^2 c^2 R^2 \right] V_y(b) \right)}{\Delta^3 c^3 R^3} V_y(b) \]

\[ \frac{\Delta^3 c^3 R^3}{\Delta V_0(b)} = V_y(b) \left[ \left[ 1 + 3\alpha C R + 2\alpha^2 c^2 R^2 \right] V_y(b) \right] \]

\[ \beta = \frac{V_y(b)}{V_0(a)} = \frac{\Delta c^3 R^3}{\Delta^2 c^3 R^3 + \Delta^2 c^2 R^2 + 5\alpha C R + 1} \]

Voltage gain of op-amp A = \[ \frac{V_0(a)}{V_y(b)} = \frac{-R_b}{R_1} \]

\[ \alpha \beta = 1 \]

\[ \frac{-R_b}{R_1} \frac{\Delta c^3 R^3}{\Delta^3 R^3 c^3 + \Delta^2 c^2 R^2 + 5\alpha C R + 1} = 1 \]

Put \( s = jw \)

\[ \frac{-R_b}{R_1} (jw)^3 R^3 c^3 = (jw)^3 R^3 c^3 + (jw)^2 R^2 c^2 + 5(jw) c c + 1 \]

\[ \frac{-R_b}{R_1} (-jw)^3 R^3 c^3 = -jw^3 R^3 c^3 - 6w R^2 c^2 + 5jw c c + 1 \]
Equating real parts we get
\[-6w^2R^2c^2 + 1 = 0 \Rightarrow 6w^2R^2c^2 = 1\]
\[\Rightarrow w_0^2 = \frac{1}{6R^2c^2} \Rightarrow f_0 = \frac{1}{2\pi V_0 R C}\]

Equating imaginary parts we get
\[-\frac{R_b}{R_1} = 1 - \frac{5}{w_0 R^2 c^2} \Rightarrow \left| \frac{R_b}{R_1} \right| = 11.30 = 29\]

or \( R_b = 29R_1 \)

Gain should be \( > 29 \) (Should be atleast 29)

and total phase shift is \( 360^\circ \).

Wein Bridge Oscillator Osc.
\( V_f \) across \( R_2 \parallel C_2 \) is applied as the terminal of op-amp.

Gain of Amp \( A = 1 + \frac{R_2}{R_2} \)

\[
\begin{align*}
V_f(\omega) &= \frac{V_{ac}}{Z_2} \\
V_f(\omega) &= \frac{Z_2}{Z_1 + Z_2} V_0(\omega) \\
I(\omega) &= \frac{V_0(\omega) - V_f(\omega)}{Z_1} \\
V_f(\omega) &= I(\omega) \cdot Z_2 \\
V_f(\omega) &= V_0(\omega) \cdot \frac{Z_1}{Z_2} \\
\frac{Z_1}{Z_2} V_f(\omega) + V_f(\omega) &= V_0(\omega) \\
V_f(\omega) \left( \frac{Z_1 + Z_2}{Z_2} \right) &= V_0(\omega) \\
V_f(\omega) &= \frac{Z_2}{Z_1 + Z_2} V_0(\omega)
\end{align*}
\]

\[
\beta = \frac{V_0(\omega)}{V_f(\omega)} = \frac{R_2}{(1 + \alpha C_2 R_2)} \left( \frac{\alpha C_1 R_1}{1 + \alpha C_2 R_2} + \frac{R_2}{(1 + \alpha C_2 R_2)} \right)
\]

\[
\beta = \frac{R_2}{(1 + \alpha C_2 R_2)} \left( \frac{\alpha C_1 R_1}{1 + \alpha C_2 R_2} + \frac{R_2}{(1 + \alpha C_2 R_2)} \right)
\]

\[
\beta = \frac{SC_1 R_2}{1 + \alpha C_1 R_1 + \alpha C_2 R_2 + \alpha^2 R_1 C_1 R_2 C_2 + \alpha R_2 C_1}
\]

\[
\beta = \frac{SC_1 R_2}{1 + \alpha C_1 + R_2 C_2 + R_2 C_1} + \alpha^2 R_1 R_2 C_1 C_2
\]

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Put \( s = jw \)

\[
\beta = \frac{jwR_2C_1}{Hjw\left(R_1C_1 + R_2C_2 + R_2C_1\right) - w^2R_1R_2C_1C_2}
\]

For \( \beta \) to be a real quantity:

\[
1 - w^2R_1R_2C_1C_2 = 0
\]

\[
\Rightarrow w^2R_1R_2C_1C_2 = 1 \Rightarrow w = \frac{1}{\sqrt{R_1R_2C_1C_2}}
\]

Freq of osc \( f_0 = \frac{1}{2\pi \sqrt{R_1R_2C_1C_2}} \)

And \( \beta = \frac{jwR_2C_1}{jw\left(R_1C_1 + R_2C_2 + R_2C_1\right)} = \frac{R_2C_1}{R_1C_1 + R_2C_2 + R_2C_1} \)

For \( R_1 = R_2 = R \) and \( C_1 = C_2 = C \)

\[
f_0 = \frac{1}{2\pi RC} \quad \beta = \frac{1}{3}
\]

For sustained osc, \( |A\beta| \geq 1 \Rightarrow |A| > 3 \)

\[
A = 1 + \frac{R_F}{R_3} = 3 \Rightarrow R_F = 2R_3
\]

If gain \( |A| > 3 \), some times it may clip the output sine wave. It is eliminated by using adaptive PB or \( \beta \).
\[ e^{-T_i/RC} = \frac{1-\beta}{1+\beta} \Rightarrow -T_i/RC = \ln\left[\frac{1-\beta}{1+\beta}\right] \]
\[ T_i/RC = \ln\left[\frac{1+\beta}{1-\beta}\right] \Rightarrow T_i = RC \ln\left[\frac{1+\beta}{1-\beta}\right] \]

Osc waveform is symmetric.
Total Time Period \( T = 2T_i = 2RC \ln\left[\frac{1+\beta}{1-\beta}\right] \)

If \( R_1 = R_2 \Rightarrow \beta = 0.5 \) and \( T = 2RC \)
Freq of Osc \( f_o = \frac{1}{2RC} \)

Osc swings from \( +V_{sat} \) to \( -V_{sat} \)
\[ \therefore V_{opp} = 2V_{sat} \]

Use of Back to Back Zener diodes

\[ R_{ac} \Rightarrow \text{limits the current drawn from op-amp.} \]
\[ I_{sc} = \frac{V_{sat} - V_{z}}{R_{ac}} \]

Asymmetric squarewave can be obtained by zener diodes with breakdown voltages \( V_{z1} \) and \( V_{z2} \)

\[ V_{opp} = 2(V_{z1} + V_{z2}) \]
\[ V_{o1} = V_x + V_D \quad V_{o2} = V_x + V_D \]
\[ T_1 = RC \ln \frac{1 + (B/V_0) |V_{o1}|}{1 - B} \quad T_2 = RC \ln \frac{1 + (B/V_0) |V_{o2}|}{1 - B} \]

Asymmetric Squarewave Generator:

\[ V_o = \beta V_{sat} + V \]
\[ = -\beta V_{sat} + V \]

By varying dc voltage \( V \) voltage to frequency conversion can be obtained.

Monostable Multivibrator: - has one stable state and one quasi-stable state. Used for generating \( V_0 \) pulse with adjustable time in response to triggering signal. Width of the pulse depends on external component connected to op-amp.
Diode $D_1$ clamps $V_C = 0.7V$

$R_4$ and $C_4$ form a differentiator, and diode $D_2$ generates a triggering pulse $V_t$, is applied to

$$\left[\beta V_{sat} + (-V_t)\right] \to V_o$$

$$\left[\beta V_{sat} + (-V_t)\right] < 0.7V \Rightarrow V_o = +V_{sat} \Rightarrow -V_{sat}$$

When $V_o = -V_{sat}$, $D_1$ is reverse biased, $C'$ charging towards $-V_{sat}$; $V_{ref} = -\beta V_{sat}$

When $V_C < -\beta V_{sat}$ (if $V_C$ is more $-ve$)

$V_o = -V_{sat} \Rightarrow +V_{sat}$
Pulsewidth $T$: 
Voltage across $c$. $V_c = V_f + (V_i - V_f)e^{-t/RC}$

$V_f = -V_{sat}$  $V_i = V_D$ (Diode forward voltage)
$V_c = -V_{sat} + (V_D + V_{sat})e^{-t/RC}$

at $t=0$ $V_c = -\beta V_{sat}$
$\beta = -1 + \left(\frac{V_D}{V_{sat}} + 1\right)e^{-t/RC}$

$(1 + V_D/V_{sat})e^{-t/RC} = 1 - \beta$

$\frac{e^{-t/RC}}{1 + V_D/V_{sat}} \geq e^{T/RC} - \frac{1 + V_D/V_{sat}}{1 - \beta}$

$T = RC \ln \left(\frac{1 + V_D/V_{sat}}{1 - \beta}\right)$ where $\beta = \frac{R_2}{R_1 + R_2}

If $V_{sat} < V_D$ and $R_1 = R_2 \Rightarrow \beta = 0.5$

$T = 0.69 RC$

For monostable operation $T_p < T$
MMV also known as Time delay opt
Triangular wave can be obtained by integrating square wave.

Triangular wave form generator using less components:
- $A_1$ - Comparator
- $A_2$ - Integrator

When $V_0' = +V_{sat}$, the voltage at point $P$ is 
$$-V_{amp} + \frac{R_2}{R_2 + R_3} \left[ +V_{sat} - (-V_{amp}) \right]$$

At $t = t_1$, the voltage at point $P = 0$. 

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\[ V_{\text{ramp}} = -\frac{R_2}{R_2 + R_3} \frac{V_{\text{sat}}}{+V_{\text{sat}} + V_{\text{ramp}}} \]

\[ -V_{\text{ramp}} + \left( \frac{R_1}{R_2 + R_3} \right) V_{\text{ramp}} = -\frac{R_1}{R_3 + R_L} \frac{V_{\text{sat}}}{+V_{\text{sat}}} \]

\[ -\frac{R_2}{R_2 + R_3} V_{\text{ramp}} = R_3 V_{\text{ramp}} + R_2 V_{\text{ramp}} \]

\[ V_{\text{ramp}} = -\frac{R_3}{R_2 + R_3} \]

\[ V_{\text{ramp}} = -\frac{R_2}{R_3} \frac{V_{\text{sat}}}{+V_{\text{sat}}} \]

at \( t = t_2 \), \( D_1 \) switches from \(-V_{\text{sat}}\) to \(+V_{\text{sat}}\)

\[ V_{\text{ramp}} = -\frac{R_2}{R_3} \frac{V_{\text{sat}}}{+V_{\text{sat}}} \]

Amplitude of \( \Delta \) wave is

\[ V_{\text{opp}} = +V_{\text{ramp}} - (-V_{\text{ramp}}) = 2 \frac{R_2}{R_3} V_{\text{sat}} \]

The op-amp switches from \(-V_{\text{ramp}}\) to \(+V_{\text{ramp}}\) during \( T_2 \)

The integrator op-amp \( V_o = \frac{-1}{RC} \int V_i \, dt \)

\[ V_{\text{opp}} = \frac{-1}{RC} \int (-V_{\text{sat}}) \, dt = \frac{V_{\text{sat}}}{RC} \frac{T_{T/2}}{T_{T/2}} \]

\[ T = 2RC, \quad \frac{V_{\text{opp}}}{V_{\text{sat}}} = 2RC, \quad 2 \frac{R_2}{R_3} V_{\text{sat}} \]

\[ T = 4RC, \quad \frac{V_{\text{opp}}}{V_{\text{sat}}} = 2RC, \quad 2 \frac{R_2}{R_3} V_{\text{sat}} \]

\[ T = 4RC, \quad \frac{V_{\text{opp}}}{V_{\text{sat}}} = 2RC, \quad 2 \frac{R_2}{R_3} V_{\text{sat}} \]

\[ T = 4 RC, \quad \frac{V_{\text{opp}}}{V_{\text{sat}}} = 2 RC, \quad 2 \frac{R_2}{R_3} V_{\text{sat}} \]

\[ T = \frac{4 RC}{R_2} \]

Freq of oscillation \( f_0 = \frac{1}{T} = \frac{R_3}{4RC, R_2} \)
Sawtooth wave generator:

\[ V_C = \frac{-V_i}{R_1} + V_{\text{ref}} \]

\[ V_{\text{ref}} \]

Ramp output:

\[ V_o \quad (V) \]

\[ V_{\text{ref}} \]

\[ V_{OC} \quad \text{Comp o/p} \]

\[ t \]

\[ +15V \]

\[ -15V \]

\[ R_3 \]

\[ Q_2 \]

\[ D_1 \]

\[ R_4 \]
rate of rise is 
set by
\[ \frac{E_i}{R_i C} = \frac{V_{op}}{t} \]

A1 - Ramp generator
A2 - Comparator

\[ V_i < 0 \Rightarrow -V_i \text{ is connected to } (-) \]
Since \[ V_i \text{ is } -V_i \text{ op of } A1 \text{ is the going ramp} \]

\[ V_{op} \text{ is connected to } (+) \text{ of } A2 \]
\[ V_{ref} \text{ is connected to } (-) \text{ of } A2 \]

When \[ V_{op} < V_{ref} \] cap C charges,
\[ op \text{ of } A2 \text{ is } -V_i \text{ at } Q_1 \text{ and } Q_2 \text{ off.} \]
\[ D_1 \text{ and } D_2 \text{ protect } Q_1 \text{ and } Q_2 \text{ from excessive PB voltages.} \]

When \[ V_{op} = V_{ref} \] op of \[ A2 \text{ is at } +V_i \text{ at } Q_1 \text{ and } Q_2 \text{ on. Cap C discharges to 0V.} \]

When \[ V_i < V_{ref} \], causes Comp op
switches to \[ -V_i \text{ at } Q_2 \text{ off and } C \]
begins to charge linearly and the

charging time \[ T_c = \frac{V_{ref}}{V_i + R_i C} \]
\[ t = \frac{1}{f} = \left( \frac{1}{R_i C} \right) \left( \frac{V_i}{V_{ref}} \right) \]
ICL 8038 Function Generators

- Monolithic IC capable of producing sine, square, triangular, sawtooth and pulse waveforms.

Main part is VCO that generates triangular and square wave. Sine wave is generated by passing triangular waveform through waveform shaping clkt.

Types of VCO:

1. Grounded capacitor VCO
2. Emitter coupled VCO.

Grounded cap VCO is used in ICL8038.
'S' is in position 1, 'C' is charged by $I_H$

$V_{TR}$ - Voltage across 'C'

When $V_{TR} \geq V_{UT}$, Schmitt Trigger changes its state to - $V_{sat}$.

'S' is connected to 2, 'C' is discharged through ct sink $I_L$.

When $V_{TR} \geq V_{LT}$, Schmitt Trigger switched to $+V_{sat}$ and 'S' is connected to 1. This sequence produces asymmetrical square wave form.

Functional ekt diagram as ICL 8038.
$Q_1$ and $Q_2$ \( \rightarrow \) Programmable ct sources.

Mag. of it set by $R_a$ and $R_b$.

$Q_3$ \( \rightarrow \) Emitter Follower. It drives base $Q_1$ and $Q_2$.

\[ i_A = \frac{V_i}{R_A} \]

is fed to 'C' directly.

$Q_4, Q_5$ and $Q_6$ forms ct mirror.

\[ i_B = \frac{V_i}{R_B} \]

is sent to ct mirror.

$Q_5$ and $Q_6$ produces $2i_B$ due to parallel arrangement.

Comp1 and comp2 and FF Schmidt Trigger.

\[ V_{LT} = \frac{1}{3} V_{cc} \quad \text{and} \quad V_{UT} = \frac{2}{3} V_{cc} \]

Assume $Q_0$ of FF is high. This saturates $Q_7$. $Q_5$ and $Q_6$ off.

' C ' charges at a rate determined by $I_{C}$.

$V_{C}$ - cap. voltage.

When $V_{C} \rightarrow V_{UT}$, Comp1 triggers and

$Q_0 \rightarrow \text{FF} \rightarrow \text{Low}$. This makes $Q_7$ off.

and ($Q_6$ and $Q_5$) ct mirror is enabled.
ct thru 'C' is \( I_C = 2I_B - I_A \)

when \( 2I_B > I_A \), cap continues to discharge and once \( V_{LT} \) is reached \( CMP2 \) triggers and makes \( Q = 1 \).

The cycle repeats.

Freq of osc \( f_0 = \frac{3V_i}{(1 - \frac{R_B}{2R_A})R_ABV_{CC}} \)

Duty cycle \( D = \left(1 - \frac{R_B}{2R_A}\right) \times 100\% \)

when \( R_A = R_B = R \)

\( f_0 = kV_i \) where \( k = \frac{1.5}{R_CV_{CC}} \)

Sine wave is obtained by using wave-shaping clkt.

Pin Diagram:

Sine wave Adjust
Sine wave out
Triangular out
Duty cycle
Freq Adjust
V+ 
FM Bias

14: NC
13: NC
12: Sine wave adjust
11: V- or GND
10: Timing cap
9: Square wave out
8: FM Sweep clkt
555 Times IC

IC 555 timer IC - highly stable device for generating accurate time delay or oscillation.

Applications: osc, pulse generator, ramp and square wave generator, mv, burglar alarm, traffic light control and voltage monitor etc.

Functional Diagram:
Gnd
Trigger
OLP
Reset

1       2       3       4       5       6       7       8

Vcc (+5V to +15V)
 discharge
 threshold
 control logic

5kΩ resistors act as voltage dividers.
It provides 2/3 Vcc to UC
1/3 Vcc to LC

Threshold determines timing interval.
Timing can be varied by applying
modulation voltage to control OLP.

C = 0.01 μF connected between 5 and ground
to bypass noise from supply.

In stable state U is high, the
OLP of power amp (80W) is low.

A rising going trigger is applied to pin 2
amp > Vcc/3

At the rising edge of trigger,
when it crosses Vcc/3, OLP of LC is high
and sets FF Q = 1 and Q = 0
During the going edge, $\text{OLP}$ is high and reset FF with $Q = 0$ and $\overline{Q} = 1$.

Pin 4 - Reset provides mechanism to reset FF.

$Q_2$ serves as a buffer to isolate reset OLP from FF and $Q_1$. $Q_2$ is driven by internal ref. Voltage $V_{ref}$.

Monostable operation:
723-General Purpose Regulator

Output voltage can be adjusted over a wide range of both the +ve and -ve regulated voltage.

Low current device but can be boosted to provide 5 amps or more by connecting external components.

Limitation of 723:
1. No built-in thermal protection
2. No short-circuit current limit

Functional Block Diagram:

Sec 1

It has 2 sections:
Zener diode, constant ct source and Ref amp produces fixed voltage of V_ref = 7V.
Sec. 2 consists of Error amp, series pass Tr Q, and ct limit Tr Q2.
The error amp compares a sample of op voltage applied at (−) and Veq applied at (+). The error signal controls the conduction of Q. These two sections are not internally connected.

Low voltage Regulator using IC 723:
Low voltage (2V to 7V) regulators can be made using IC 723.
Voltage to Freq converter:
produces an o/p whose freq is
for external control i/p voltage.
o/p = sine, square, pulse

\[ f_o = K_v \cdot V_i \]

\( K_v \) - Sensitivity of V\( \rightarrow \)F converter Hz/Volt

It provides analog to digital conversion.
It is functioning like VCO.

ICVFC32: V\( \rightarrow \)F converter

A1 \( \rightarrow \) V\( \rightarrow \)I converter
A2 - Comparator

[Diagram of the circuit]
It uses charge balancing diode charging and discharging results in pulse whose Iref freq is ppl to ic Ref voltage.

\[ I_i = \frac{V_i}{R} \]  
R is selected such that \( I_i < 1 \text{mA} \)

'S' is open, \( I_i \) flows through \( C_i \) and produces \( V_{oi} = (-\text{ve}) \) ramp signal.

When \( V_{oi} \to 0 \), CMP triggers and sends a trigger signal to \( mV \). \( mV \) closes 'S'.

At \( V_{oi} \to 0 \), \( mV \) turns on for \( T_H \)

\[ T_H = \frac{7.5 \times C}{1 \times 10^{-3} \text{I}_i} \]  
7.5 - Threshold of \( mV \)
1mA - charging \( C_i \)

If 'S' is closed (1mA - \( I_i \) flows out of \( A_i \)), during \( T_H \), \( V_{oi} \to (\text{ve}) \) going ramp

\( T_L \to V_{oi} \to (-\text{ve}) \) going ramp \& returns to zero.
\[ T_L = \frac{C_i \Delta V_{b1}}{I_i} \]

\[ I_i T_L = (1mA - I_i) T_H \]

\[ \Delta V_{b1} = (1mA - 2I_i) T_H / C_i \]

\[ T_L + T_H = \frac{1mA \cdot T_H}{I_i} \]

\[ I_i = \frac{V_i}{R} \quad \text{and} \quad \gamma_0 = \frac{1}{T_L + T_H} \]

\[ \gamma_0 = \frac{V_i}{7.5 \cdot R \cdot C} \Rightarrow \gamma_0 \propto V_i \]

Duty cycle \( \gamma \) = 100 \( \frac{V_i}{R \cdot 1mA} \)

Linearity error: 0.005\% to 0.025\%.

Freq to Voltage Converter

![Circuit Diagram]
FM converter produces o/p voltage whose amp is ft of i/p signal freq. It is FM detector / FM discriminator.

\[ V_o = K_f f_i \]

\( K_f \) - Sensitivity in v/Hz.

I/p freq is applied to Amp and o/p is obtained from Amp A1.
For each –ve spike of \( V_{o1} \), cmp triggers
mv.
mv has threshold of \( 7.5 \text{V} \) and charging
c at \( 9 \text{mA} \).
mv closes ‘s’.

\[
T_H = \frac{CV_i}{I} = \frac{C \times 7.5}{1 \times 10^{-3}}
\]

\( f_i \rightarrow \text{I} \rightarrow f_{eq} \)

pulled \( c_t = f_i \times 1 \text{max} \times T_H \)
counting balancing \( c_t = \frac{V_0}{\text{R}} \)

\[
V_0 = 10^{-3} \times T_H \times R \times f_i
\]

Apply \( T_H \Rightarrow V_0 = 7.5 \times R \times c_i \)

\[
V_0 \propto f_i
\]

Discharge \( c_i \) creates ripple \( m_i V_0 \)
max. ripple voltage \( V_0 \text{max} \) \( \frac{(1 \text{mA}) \times T_H}{c_i} \)

\[
V_0 \text{max} = \frac{7.5 \times c}{c_i}
\]
VIDEO AMPLIFIER:

- Should provide constant gain over the video transmission freq.
- Freq range: 20 Hz to several MHz.
- TV BW: 4 to 6 MHz.

For low freq applications op-amp uses high loop gain. High loop gain provides large IIP impedance, very small 1IP, and minimizes gain error.

High voltage gain gives freq response. To stabilize the amp response reduced load resistance and -ve FB are employed simultaneously.

Type 733 Video Amp:

2 stage
- differential IIP
differential OIP
- and wide band video amp
- BW = 120 MHz
Features of IC 733

1. Wide BW of 120 MHz.
2. I/P resistance of 250 kΩ.
3. Gains of 10, 100, and 400 are selectable.
5. High CMRR at high freqs.
Isolation amplifier:
Amp in which there is no physical contact between LIP and OLP. They are used in applns reqd very large common mode voltage b/w LIP and OLP.

Signal transmission is through an optical coupler which acts as 1:1 current trans later. Current at LIP is replicated to OLP.

Applns: use in medical instrumentation, applns where patient must be isolated and protected from leakage etc.

Isolation amp Inc consists of:
1. Ga As LED
2. Photo diode
3. LIP and OLP amplifiers

The LIP modulates the light of OLP as LED. Light is detected by photo diode and converted to an electrical signal.

The main requirement is LIP and OLP should be linear.

ISO 100 isolation amplifier: optically coupled isolation amp. It offers high accuracy, linearity and good stability against time and temp.
Opto coupler - is a solid state component in which light emitter, light path and light detector are all enclosed within the component. It provides electrical isolation between two circuits hence it is also known as opto-isolator.

Schematic diagram:

It consists of GaAs LED and photodetector. Photodetector may be p-n diode, photo diodes, photo transistors or phototransistor.

LED converts ILP voltage to PPL light intensity.

Photodetector converts light intensity to OLP voltage.

Response time is very small hence can be used to transmit data in MHz range.
Characteristics of optocouplers:

1. Collector-Emitter Voltage: Max. voltage that can be applied across collector and emitter of phototransistor before it may breakdown.
2. Forward Current: Current passing through LED.
3. Forward Voltage: Voltage dropped across LED when it is turned on by iIP Vii.
4. Collector dark: Collector flows through opto when it is turned off.
5. Collector-emitter saturation voltage:
   Voltage available blw collector and emitter when Tr is saturated.
6. Isolation resistance: Very high to give good isolation blw iIP and opto.
7. Response Time: The rise and fall times are time duration that iIP need to rise from zero to max and to fall from max. to zero.
8. Cut-off freq: The freq at which at 0IP becomes half the max. amplitude. It determines the operating BW.
9. Current transfer ratio: ratio of iIP to iIP e'.
Important Features:
1. An isolation voltage of 2500 Vrms can be obtained.
2. Switching speed of $t_{PHL} = 0.8 \mu s$ and $t_{PLH} = 2 \mu s$ is possible.
3. It is TTL compatible.

Adv:
1. Electrical isolation (100 V rms and 100 V rms) of the order of 5 MV.
2. Response time is less.
3. Capable of wide band signal transmission.
4. Easy interfacing with logic devices.
5. Compact and portable.
6. More efficient than isolation transformers and relays.
7. Noise, transients are completely eliminated.
Fibre Optic IC:

Optics provides adv. of larger BW and re-configurable characteristics. Electroni devices provide active component in information handling system.

Opto-Electronic IC (OEIC) - Integration of electronic and optical component and optical inter-connect.

Fiber is an optical interconnect medium. It provides large BW, high speed data, transmission and immunity against mutual interference and crosstalk.

Block Diagram of OEIC:

It combines the functions of optical detection, electronic functions such as switching and amplification and light transmission.
It transfers electrical signal from CiP to o/P without any electrical connection. The isolation blw CiP and o/P depends on distance blw LED and photodetector.

It is used as an interface blw high voltage and low voltage systems.

Circuit arrangement:

Light emitted from LED depends on Vi. Light incident on photodiode produces reverse et the drop across R0 depends on CiP, and it varies ppb to CiP.

Opto-coupler ICs:

TLP112 - mini flat coupler IC. It consists of GaAlAs LED optically coupled to photodiode transistor assembly.
Transmitter consists of LED LED lines on/off based on the information to be sent. The signal is amplified, reshaped, retimed and then transmitted. The receiver senses the attenuated light pulses. Then the pulses and processed before detection. Then the receiver converts the light pulses to electrical signal. The electrical signal is regenerated and distributed.