ac voltage at line frequency when the switch is set to Line or from the vertical amplifier when the switch is set to INT. when set for internal triggering (INT); the trigger circuit receives its input from the vertical amplifier. When the vertical input signal that is being amplified by the vertical amplifier reaches a certain level; the trigger circuit provides a pulse to the sweep generator, there by ensuring that the sweep generator output is synchronized with the signal that triggers it.

One type of circuit frequently used in the "trigger circuit" is called a schmitt trigger or a voltage level detector. Basically the schmitt trigger compares an input voltage, in this case from the vertical amplifier with a voltage at a point in the circuit. when the input voltage exceeds the voltage to which it is being compared, the circuit changes states, which means the output voltage goes to high state. The point at which this occurs is called the upper trigger point (UTP). when the input voltage drops below a certain level called the lower trigger point, the schmitt trigger output returns to its original level, & the output of the circuit is a square wave. unless this square wave is of very short duration it will not be suitable to trigger the sweep generator directly. It is common practice to apply the square wave to an RC circuit called a differentiator whose output is a short duration spike suitable for triggering the sweep generator.

Delay line:

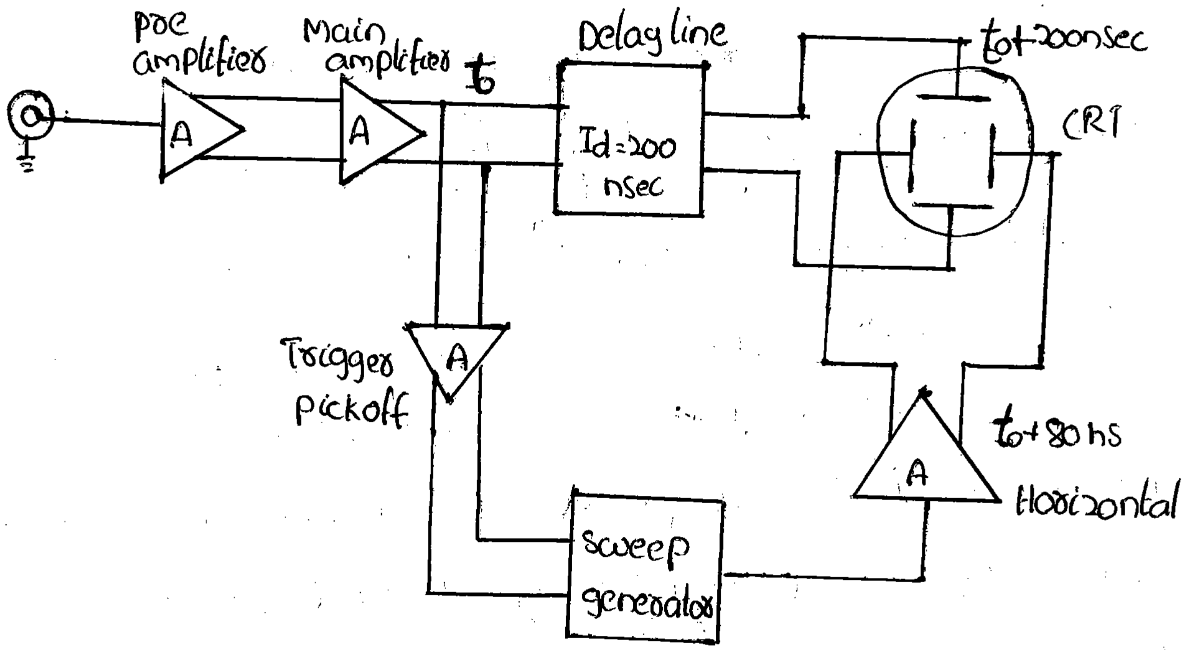
The delay line is defined as a circuit that is used to introduce a delay in feeding the output of vertical amplifier to the vertical deflection plates.

All electronic circuits in the oscilloscope like attenuators, timebase generators, amplifiers cause some amount of time delay while transmitting signal voltage to deflection plates. In a CRO a part of the signal being applied to the vertical plates is used to initiate time base signal. This is called triggering.

Now the trigger circuit will cause a delay because of the inherent inductances & capacitances of the circuit, elements & wires. This delay will be of the order of 80-200nsec. Hence the horizontal signal & vertical signal are not synchronised owing to this, the details of the leading edge & the trailing edge of a pulse are lost.

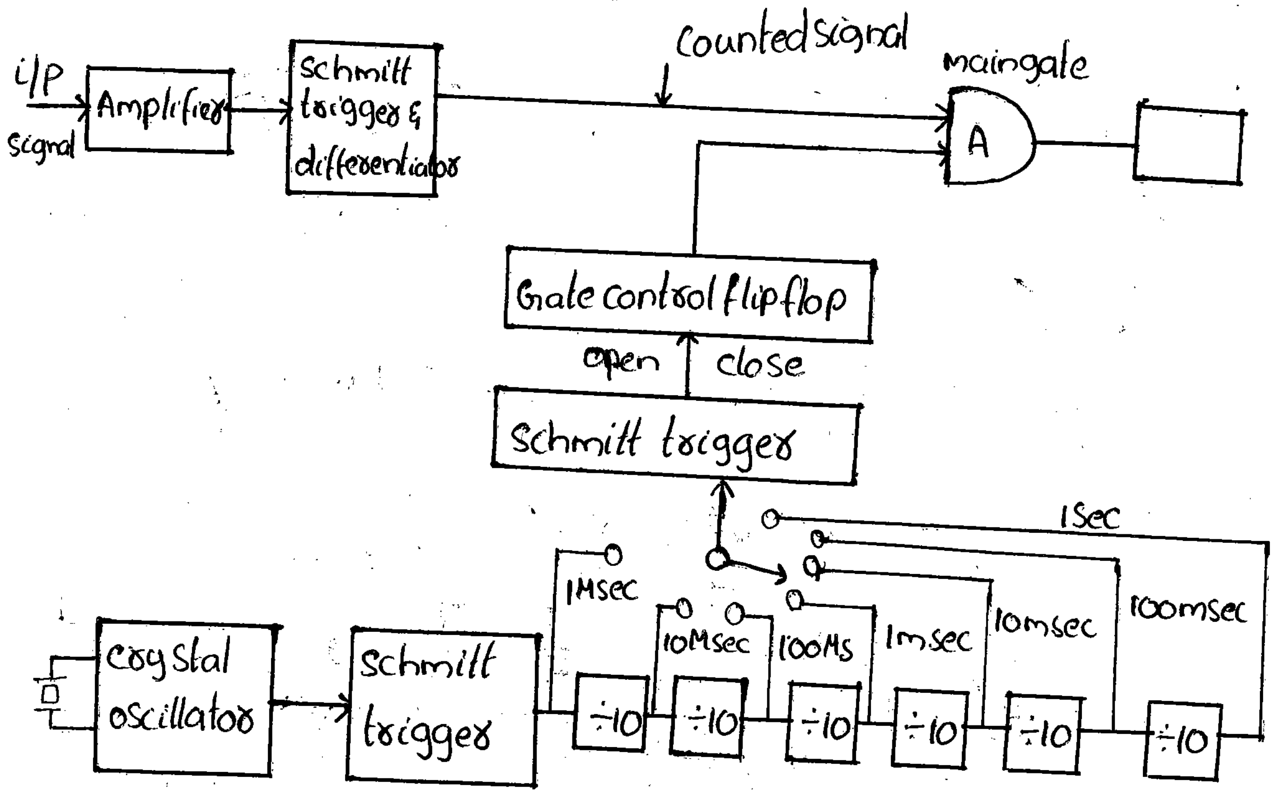
Hence a delay line will be incorporated in the circuit. A delay of the vertical signal allows the horizontal sweep to start before vertical deflection.

The schematic after the inclusion of the delay



Measurement of frequency

Frequency can be accurately measured by counting the number of cycles of the unknown signal for a precisely controlled time interval.



when the output of the And gate is high, it is counted as 1, irrespective of the shape. The wave shape is not important for counting.

there are two signals

1. The input signal whose frequency is to be measured
2. The gating signal that determines the length of

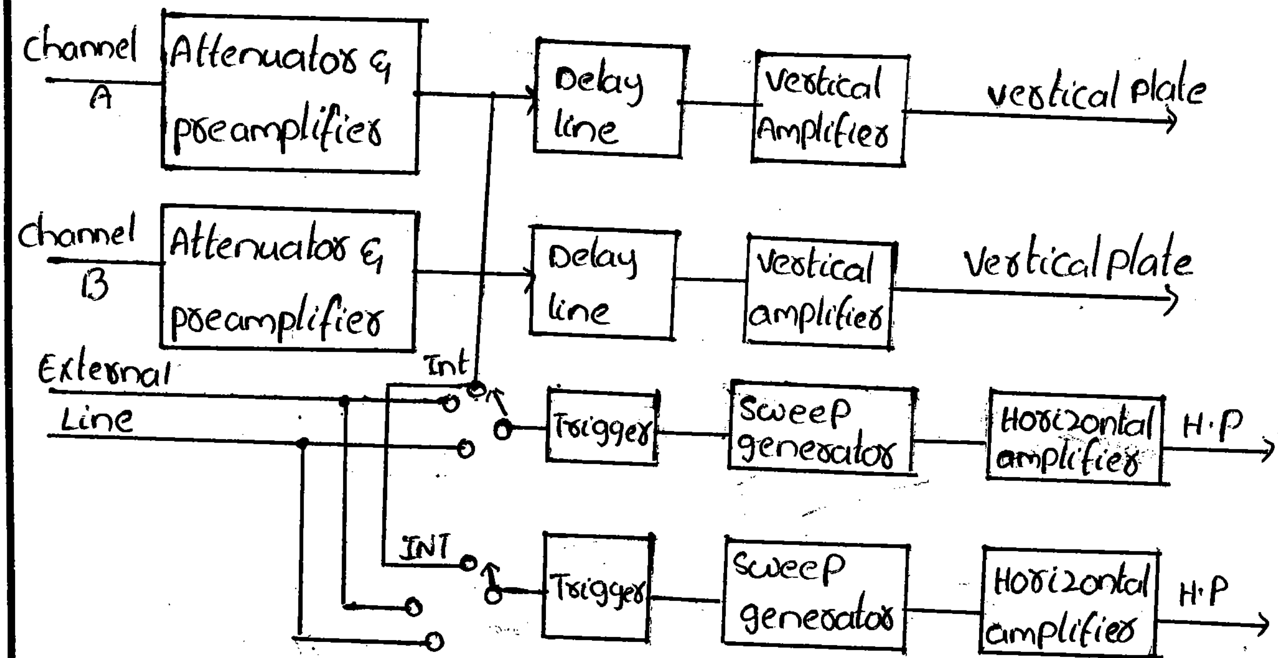
time during which the decimal counting assemblies (DCA) are allowed to accumulate pulses.

The input signal is amplified & passed to a Schmitt trigger. Here it is converted to a square wave with very fast rise & fall times then they are differentiated & clipped. As a result the signal that arrives at the input to the main gate consists of a series of pulses separated by the period of the original input signal.

The internal oscillator frequency is 1MHz. The time base output is shaped by a schmitt trigger so that positive spikes 1Msec apart are applied to a number of decade dividers. In fig six decade dividers assemblies, (DDA) are used, the outputs of which are connected to a timebase selection switch. This allows the time interval to be selected from 1 Msec to 1 sec. The first output pulse from the time base selection switch passes through a schmitt trigger to the gate control flip-flops.

The gate flip-flop assumes a state such that an enable signal is applied to the main gate. Since this is an AND gate, the input signal pulses are allowed to enter the DCA's & they are totalised & displayed. This continues until the second pulse from the DCA's arrives at the control flip flop. The main gate closes & no further pulses are admitted to the DCA's. The display of DCA is now in a state that corresponds to the number of input pulses received during a precise time interval which was determined by the time base. usually the time base selection switch moves the decimal point in the display area allowing the frequency to be read directly in Hz, KHz, or MHz.

Dual beam CRO

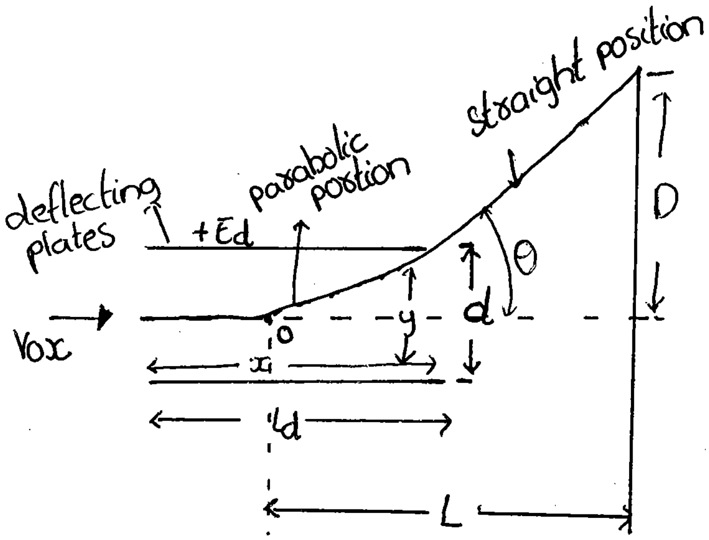


The dual beam oscilloscope has two separate electron beams, therefore two completely separate vertical channel. the two channels may have a common time base system or they may have independent time base circuits as shown in figure. An independent time base allows different sweep rates for two channels but increases the size & weight of the oscilloscope.

Two methods are used for generating the two electron beams with in the CRT. The first method uses a double gun tube. This allows the brightness & focus of each beam to be controlled separately but it is bulkier than a split beam.

In the second method known as split beam, a single electron gun is used. A horizontal splitterplate is place between the last anode & the Y deflecting plates. This plate is held at the same potential as the anode & it goes along the length of the tube, between the two vertical deflecting plates. It therefore isolates the two channels. The split beam arrangment has half the brightness of a single beam, which has disadvantage at high frequency operation. An alternative method of splitting the beam, which improves its brightness is to have two apertures in the last anode, instead of one; so that two beams emerge from it.

The disadvantage of the split beam construction is that two display may have noticeably different brightness, if operated at widely spaced sweep speeds. the brightness & focus controls also affect the two traces at the same time.



The loss of potential Energy when electron moves from cathode to accelerating anode is

$$P.E = eE_a$$

where e = charge of electron, colomb
E_a = accelerating anode potential, V

Any electron entering the field between parallel plates will experience a force in the Y-direction & will be accelerated in that direction.

The gain in kinetic energy by an electron is

$$K.E = \frac{1}{2} m V_{ox}^2$$

where m = mass of electron, 9.1×10^{-31} kg
V_{ox} = velocity of electron when entering the field of deflecting plates m/s

⇒ Loss in P.E = gain in K.E

$$eE_a = \frac{1}{2} m V_{ox}^2 \quad \Rightarrow \boxed{V_{ox} = \sqrt{\frac{2eE_a}{m}}}$$

V_{ox} is the velocity in the x direction, & there is no initial velocity in Y direction. The displacement 'y' at any instant 't' in the Y direction can be calculated as follows

$$y = \frac{1}{2} a_y t^2 \quad \Rightarrow S = ut + \frac{1}{2} at^2$$

where a_y = acceleration of electron in Y direction

∴ Force $F_y = ma_y \Rightarrow a_y = \frac{F_y}{m}$

F_y is the force acting on an electron in Y direction

$$F_y = e\frac{E_d}{d}$$

where E_d = potential between deflecting plates

$$\Rightarrow a_y = \frac{e\mathcal{E}_y}{m} \quad \& \quad y = \frac{1}{2}\frac{e\mathcal{E}_y}{m}t^2$$

The displacement in x-direction

$$x = V_{ox}t \quad \text{(since velocity is constant)}$$

$$\Rightarrow t = \frac{x}{V_{ox}}$$

$$\therefore \quad y = \frac{1}{2}\frac{e\mathcal{E}_y}{m}\left(\frac{x}{V_{ox}}\right)^2 \Rightarrow y = \frac{1}{2}\frac{e\mathcal{E}_y}{mV_{ox}^2}x^2$$

This is the equation of parabola

The slope at any point (x,y) is $\frac{dy}{dx}$

$$\frac{dy}{dx} = \frac{d}{dx}\left[\frac{1}{2}\frac{e\mathcal{E}_y}{mV_{ox}^2}x^2\right]$$

$$= \frac{1}{2}\frac{e\mathcal{E}_y}{mV_{ox}^2}2x$$

$$\frac{dy}{dx} = \frac{e\mathcal{E}_y}{mV_{ox}^2}x$$

Let l_d be the length of the deflecting plates i.e $x = l_d$

$$\text{Slope } \tan\theta = \frac{e\mathcal{E}_y}{mV_{ox}^2}x$$

But $\tan\theta = \frac{y}{x}$ [from graph]

$$x = \frac{y}{\tan\theta} \Rightarrow \frac{\frac{1}{2}\frac{e\mathcal{E}_y}{mV_{ox}^2}x^2}{\frac{e\mathcal{E}_y}{mV_{ox}^2}x} \quad [\text{sub } x = l_d]$$

$$\Rightarrow x = \frac{l_d}{2}$$

... deflection D on the screen is given by

$$\tan\theta = \frac{D}{L} \Rightarrow D = L\tan\theta$$

$$D = L \frac{e\varepsilon_y}{m V_{ox}^2} l_d$$

$$= L \frac{eE_d}{m d V_{ox}^2} l_d$$

But $V_{ox}^2 = \frac{2eE_a}{m}$

$$D = L \frac{eE_d}{md\left(\frac{2eE_a}{m}\right)} l_d$$

$$D = \frac{L E_d l_d}{2dE_a}$$

Deflection Sensitivity:

The deflection sensitivity is defined as the deflection of the screen per unit deflection voltage.

$\therefore$ Deflection sensitivity $S = \frac{D}{E_d} = \frac{L l_d}{2dE_a}$ m/V

The deflection factor of a CRT is defined as the reciprocal of sensitivity

$\therefore$ Deflection Factor $G = 1/S = \frac{2dE_a}{L l_d}$ V/m

Problems on deflection sensitivity.

→ Calculate the maximum velocity of the beam of electrons in a CRT having a cathode anode voltage of 800V. Assume that the electrons to leave the cathode with zero velocity. charge of electron = 1.6×10^{-19} C & mass of electron = 9.1×10^{-31} kg

Velocity of electron $V_{ox} = \sqrt{\frac{2eE_a}{m}} = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 800}{9.1 \times 10^{-31}}} = 16.8 \times 10^3$ m/s

→ An electrically deflected CRT has a final anode voltage of 2000V & parallel deflecting plates 1.5 cm long & 5mm apart. If the screen is 50 cm from the centre of deflecting plates

1. find beam speed 2. the deflection sensitivity of tube & deflection factor

beamspeed or velocity of beam $V_{ox} = \sqrt{\frac{2eE_a}{m}} = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 2000}{9.1 \times 10^{-31}}}$ = ~~[illegible]~~ 26.5×10^6 m/s

Deflection sensitivity $S = \frac{D}{E_d} = \frac{Ll_d}{2dE_a}$ m/V

~~L = 50cm = 0.5m~~

= ~~[illegible]~~

$V_a = 2000V$, $L = 50cm$; $d = 5mm$; $l = 1.5cm$

$$= \frac{1.5 \times 10^{-2} \times 50 \times 10^{-2}}{2 \times 5 \times 10^{-3} \times 2000} = 3.75 \times 10^{-4} \text{ m/V}$$

Deflection factor $G = \frac{1}{S} = \frac{1}{3.75 \times 10^{-4}} = 2666.667$ V/m

→ what should be the accelerating anode voltage in CRT if $l = 2cm$ $L = 30$ cm & deflection for 50 V is 1cm on the screen. The plates are separated by 1cm

$l_d = 2$ cm $L = 30$cm $E_d = 50V$, $D = 1$ cm ; $d = 1$cm

$$S = \frac{D}{E_d} = \frac{1 \times 10^{-2}}{50} = 2 \times 10^{-4} \, m/V$$

Now $S = \frac{L l_d}{2 d V_a}$

$$2 \times 10^{-4} = \frac{2 \times 10^{-2} \times 30 \times 10^{-2}}{2 \times 1 \times 10^{-2} \times V_a} \Rightarrow V_a = 1500V$$

→ A CRT has an anode voltage of 2000V & parallel deflecting plates 2cm long & 5mm apart. The screen is 30 cm from the centre of the plates. Find the input voltage required to deflect the beam through 3cm. The input voltage is applied to the deflecting plates through amplifiers having an overall gain of 100

$$D = \frac{L E_d l_d}{2 d E_a}$$

∴ voltage applied to deflecting plates $E_d = \frac{2 d E_a D}{L l_d}$

$$= \frac{2 \times 5 \times 10^{-3} \times 2000 \times 3 \times 10^{-2}}{0.3 \times 2 \times 10^{-2}} = 100V$$

∴ Input voltage required for a deflection of 3cm $= \frac{E_d}{gain} = 1V$

→ calculate velocity of the electron beam in an oscilloscope if the voltage applied to its vertical deflection plates is 2000V. Also calculate the cut off frequency if the maximum transit time is 1/4 of a cycle. The length of horizontal plates is 50mm.

Velocity of electron beam $V_{ox} = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 2000}{9.1 \times 10^{-3}}} = 26.5 \times 10^6$ m/s

Cut off frequency $f_c = \frac{V_{ox}}{4l} = \frac{26.5 \times 10^6}{4 \times 50 \times 10^{-3}} = 132.5 \times 10^6$ Hz

Transit time $t = \frac{l}{V_{ox}}$ → limitation of upper frequency limit. An upper limiting freq defined as the freq at which the transit time is equal to one quater of the period of the voltage applied to vertical plates. $f_c = \frac{1}{4t} = \frac{V_{ox}}{4l}$

→ In an experiment, the voltage across a 10kΩ resistor is applied to CRO. The screen shows a sinusoidal signal of total vertical occupancy of 3cm & total horizontal occupancy of 2cm. The front panel controls of v/div & time/div are on 2V/div & 2ms/div respectively. Calculate the rms value of the voltage across the resistor & its frequency.

of two characteristics

conformity & Number of significant figures

* It is the measure of consistency or repeatability of measurement

Conformity: A resistor having true value as 2385692 Ω, which is being measured by an ohmmeter. Now, the meter is consistently measuring the true value of the resistor. But reader can read consistently 2.4 MΩ due to nonavailability of proper scale. The value 2.4 MΩ is estimated by the reader from available scale. The error create due to the limitation of the scale reading is a precision error.

Significant figures: precision of measurement is obtained by from the number of significant figures, in which reading is expressed. The significant figures convey the actual information about magnitude & the measurement precision of quantity. Ex: 110 Ω → 109 Ω or 111 Ω → 3 significant figures

* more significant figures, the greater is precision of measurement.

The precision can be mathematically expressed as

$$P = 1 - \left| \frac{X_n - \overline{X_n}}{\overline{X_n}} \right|$$

X_n = Value of n^{th} measurement

$\overline{X_n}$ = Average of the set of measured values

Ex: The table shows the set of 5 measurements recorded in the laboratory calculate the precision of 3rd measurement

Measurement no:	1	2	3	4	5
value of measurement:	49	51	52	50	49

The average value $\overline{X_n} = \frac{\text{Sum of readings}}{\text{Number of readings}} = \frac{251}{5} = 50.2$

the value of 3rd $X_n = 52$ where $n = 3$

$$P = 1 - \left| \frac{X_n - \overline{X_n}}{\overline{X_n}} \right| = 1 - \left| \frac{52 - 50.2}{50.2} \right| = 0.964 \text{ i.e } 96.4\%$$

↓
P

calculate the value of the multiplier resistor required for 100 Vrms range on the AC voltmeter using Half wave rectifier with $I_{fsd} = 100 \mu A$ & $R_m = 500\ M\Omega$

$I_d = I_{fsd}$

Half $R_s = \frac{0.45\ V_{rms}}{I_{dc}} - R_m$

Full $R_s = \frac{0.9\ V_{rms}}{I_{dc}} - R_m$

→ Determine the period of Integration of dual slope integrating type DVM, which has an integrating capacitor of 0.1 MF & R = 10 kΩ if the reference voltage is 2V & the o/p of the integrator is not to exceed 10V.

Integrator time constant = CR
= 0.1 MF × 10 kΩ = 10 msec

Reference voltage V_R = 2V

Integrator o/p $= \frac{2V}{10\,msec} = 200\ V/sec$

Maximum o/p of integrator = 10V

∴ period of integration $= \frac{10V}{200 V/sec} = 0.05\ sec$
= 50 ms

$V_o = \frac{V_{ref}}{RC} T_{int}$

$10 = \frac{2}{10} T_{int}$

$\frac{100}{2} =$

* Formula

$$V_o = \frac{V_{ref}}{RC} T_{integrate}$$