An application and oscillators
Comparator

If $V_A > V_B$ then $V_{out} = V_{CC}$, otherwise $V_{out} = V_{EE}$.
Can use this to “trigger” at a threshold, similar to your scope.

Here, treating $V_{EE} = Gnd$
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Design of a smoke alarm

We have enough tools to start designing things.

Learning the electronics design process is part of our goal here.

As we design, we might need to learn some new tools.

So, let’s go through the design of a smoke alarm.
In lab next week you will make a “burglar alarm”.

Start with an overview of the required stages:

Sense smoke → Process information → Generate alarm
Smoke alarm

Safety checks:
  Battery warning
  Test feature
Oscillator

We can make an oscillator with any positive feedback
Oscillator

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Oscillator

We can make an oscillator with an op-amp

The $I_+ = I_- = 0$ golden rule means we can calculate $V_+$ and $V_-$ in terms of $V_1$.

$V_+ = ?$

$V_2 = V_- = ?$
Oscillator

We can make an oscillator with an op-amp

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$V_+ = V_1/2$

$V_2 = V_- = V_1 - IR$
Oscillator

We can make an oscillator with an op-amp

\[ \begin{align*}
I_+ &= I_- = 0 \text{ golden rule means we can calculate } V_+ \text{ and } V_- \text{ in terms of } V_1. \\
V_+ &= V_1/2 \\
V_2 &= V_- = V_1 - I R \\
\text{where } I &= C \frac{dV_2}{dt}
\end{align*} \]
The $I_+ = I_- = 0$ golden rule means we can calculate $V_+$ and $V_-$ in terms of $V_1$.

$$V_+ = \frac{V_1}{2}$$

$$V_2 = V_- = V_1 - I R$$

where $I = C \frac{dV_2}{dt}$

What is $V_1$?
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What is $V_1$?

$$T \approx 2.2RC$$
555 timer

Oscillators and other timing applications are common, so there is a timer chip
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\[ t = 1.1 \times R1 \times C1 \]
555 timer

Oscillators and other timing applications are common, so there is a timer chip.
Digital potentiometer

We can adjust the frequency by changing the resistance with a potentiometer. It is more common now to use a “digital potentiometer” (cheaper than trimpot).
Voltage controlled oscillator

It is sometimes useful to control an oscillator with a voltage, or to encode a voltage as a frequency.
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It is sometimes useful to control an oscillator with a voltage, or to encode a voltage as a frequency.

Out2 is either high or low as output of comparator.

Out1 linearly ramps down until $V_{EE}/2$, then Out2 flips to $V_{CC}$.
Ramp rate proportional to $V_{in}$.
Voltage controlled oscillator

It is sometimes useful to control an oscillator with a voltage, or to encode a voltage as a frequency.

Out2 is either high or low as output of comparator.

Integrator with $V_{in}$ control

Schmitt trigger

Negative feedback

nMOS
Voltage controlled oscillator

It is sometimes useful to control an oscillator with a voltage, or to encode a voltage as a frequency.

Out2 is either high or low as output of comparator.

Integrator with $V_{in}$ control

Schmitt trigger

If $Out1 > 0$ & $Out2 = V_{EE}$, then nMOS = off.

$C$ charges as an integrator

Out1 linearly ramps down until $V_{EE}/2$, then Out2 flips to $V_{CC}$.

Ramp rate proportional to $V_{in}$.
Voltage controlled oscillator

It is sometimes useful to control an oscillator with a voltage, or to encode a voltage as a frequency.

Out2 is either high or low as output of comparator.

Integrator with $V_{in}$ control

Out1 linearly ramps up until $V_{CC}/2$, then Out2 flips to $V_{EE}$. Ramp rate proportional to $V_{in}$.

Schmitt trigger

If $Out1 < 0 \& Out2 = V_{CC}$, then nMOS = on.

C charges as an integrator.

Mathematical equations:

$I = \frac{(V_{in} - V_{in}/2)}{100k} = \frac{V_{in}}{200k}$

$I_D = \frac{(V_{in}/2)}{50k} = \frac{V_{in}}{100k}$

$I_C = I - I_D = V_{in}(\frac{1}{200k} - \frac{1}{100k})$

$I_C = I - I_D = -\frac{V_{in}}{200k}$

$C \frac{d(V_{in}/2 - V_{out1})}{dt} = -\frac{V_{in}}{200k}$

$C \frac{dV_{out1}}{dt} = \frac{V_{in}}{200k}$
Voltage controlled oscillator

It is sometimes useful to control an oscillator with a voltage, or to encode a voltage as a frequency.
Sine wave oscillator

We could get a sine wave oscillator in a few ways:
0). Use a computer to rapidly change the resistance in a digital potentiometer used in a voltage divider
Quiz
Quiz

What is wrong with these circuits?
Quiz

What is wrong with these circuits?

![Circuit Diagram 1](image1)

- $V_{CC} = +5\, V$
- $R_1 = 350\, k\Omega$
- $R_C = 500\, k\Omega$
- $R_E = 1\, k\Omega$
- $R_2 = 100\, k\Omega$
- $C_{in}$
- $Q_1$
- $V_{out}$
- $C_{out}$
- $V_{in}$
- $V_{EE}$

![Circuit Diagram 2](image2)

- $V_{CC} = +5\, V$
- $R_1 = 350\, k\Omega$
- $R_C = 1\, k\Omega$
- $R_E = 500\, k\Omega$
- $R_2 = 100\, k\Omega$
- $C_{in}$
- $Q_1$
- $V_{out}$
- $C_{out}$
- $V_{in}$
- $V_{EE}$