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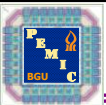
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## Analog Electronic Circuits

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## Lesson #7 Outline

- Comparators
  - Voltage comparator – basic characteristics
  - Internal circuit
  - Propagation time and overdrive
  - Output stage
- Basic applications
  - Level detection, window, counter, PWM, ON-OFF control
- Schmitt trigger
  - Inverting and noninverting
  - Single supply
- Advanced applications
  - Oscillators



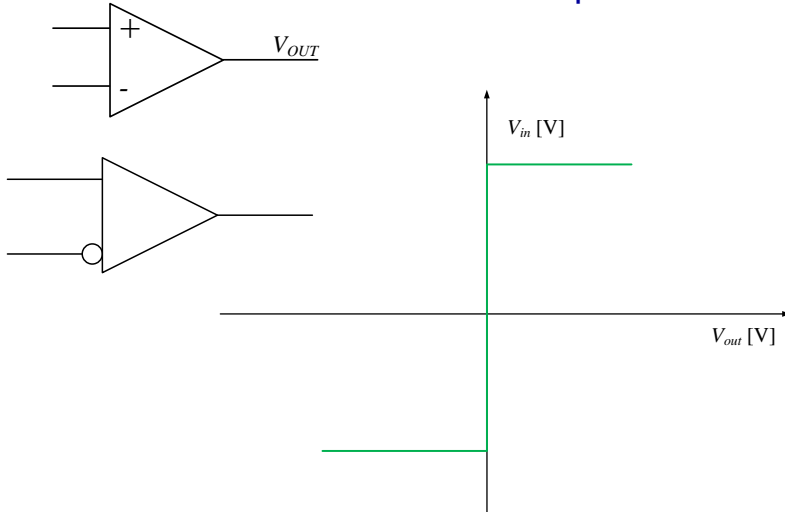
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### Comparator



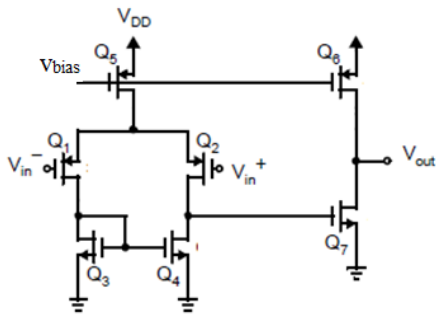
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### Internal circuit



Simple differential

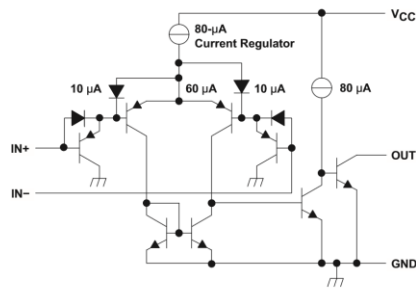
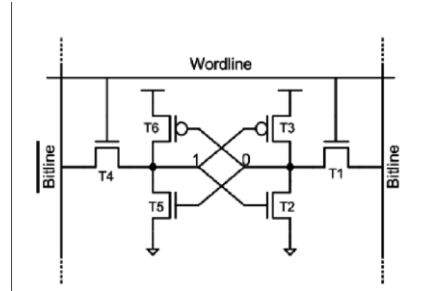
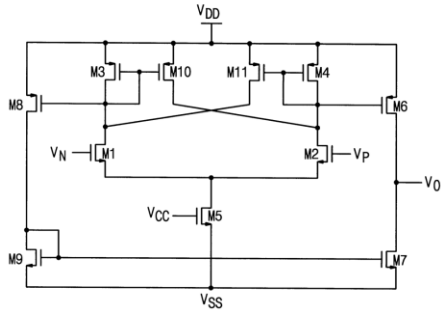


Figure 6. Schematic (Each Comparator)

LM339 (TI)



### Internal circuit



Latched output



### Propagation time and overdrive

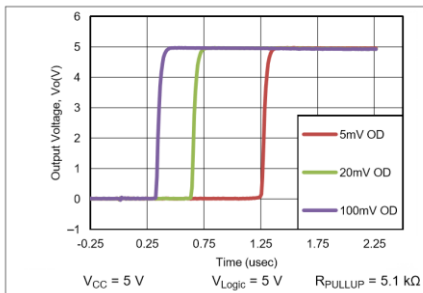


Figure 8. Response Time vs Output Voltage (Positive Transition)

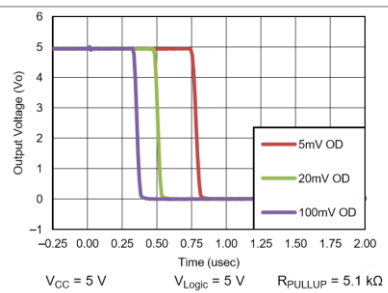
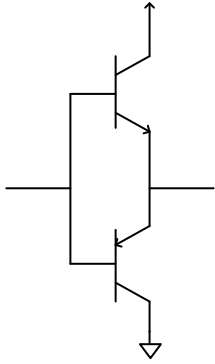


Figure 9. Response Time vs Output Voltage (Negative Transition)

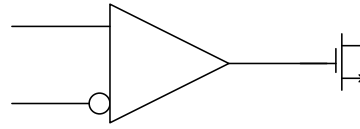
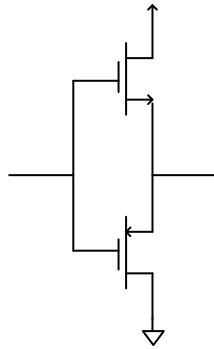
(TI)



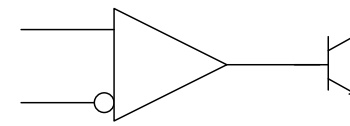
### Output stage



Push-pull

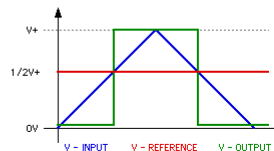
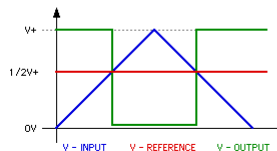
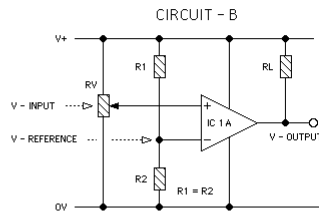
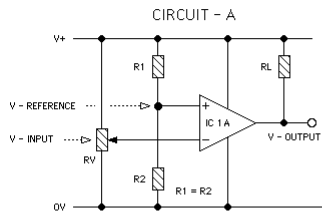


Open-drain  
(Open-Collector)



### Basic operation

BASIC OPERATION OF VOLTAGE COMPARATORS  
©ROB PAISLEY 2002  
Comparator Operation



<http://home.cogeco.ca/~rpaisley4/CircuitIndex.html>



Applications –basic

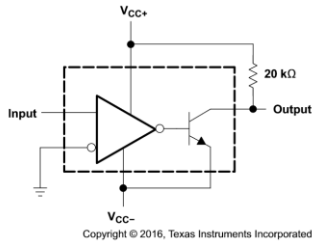


Figure 13. Zero-Crossing Detector

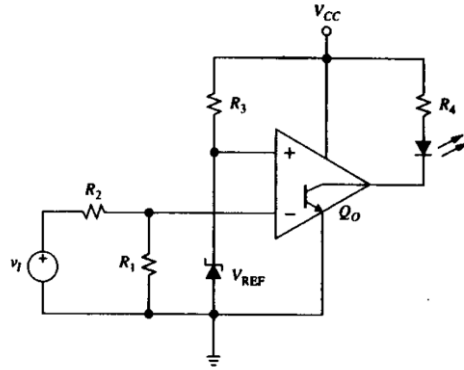
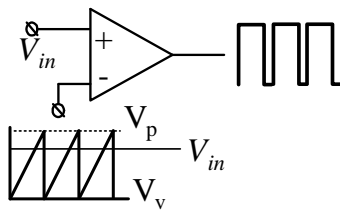


FIGURE 9.11 Basic level detector with optical indicator.

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Applications –basic



PWM

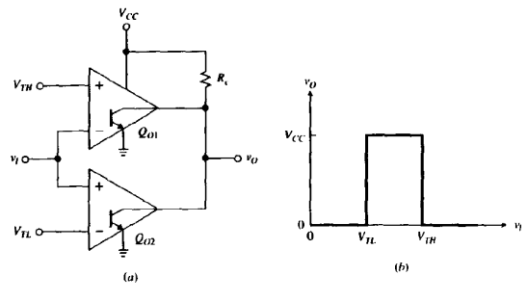


FIGURE 9.13 Window detector and its VTC.

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### Applications –basic

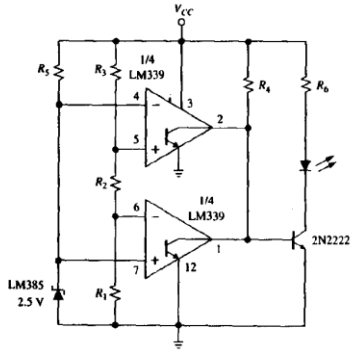
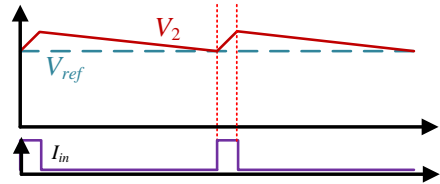
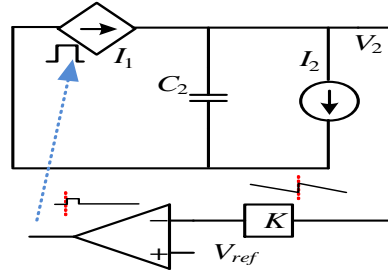
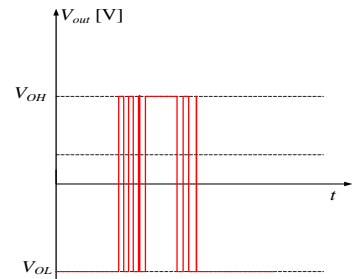
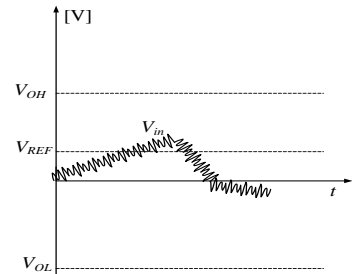
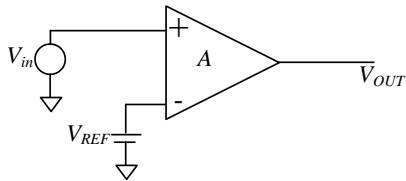


FIGURE 9.14 Power-supply monitor; LED glows as long as  $V_{CC}$  is within specification.

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### Comparator noise





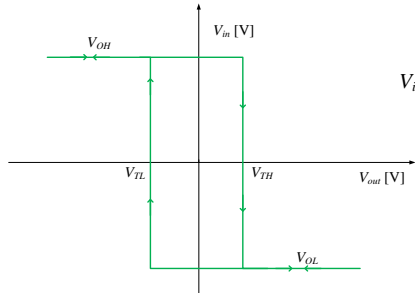
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## Schmitt Triggers

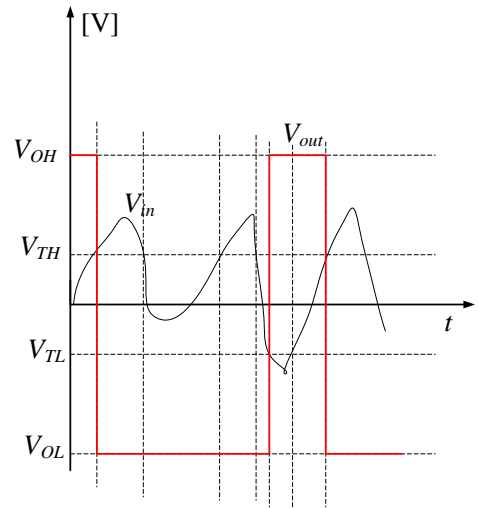
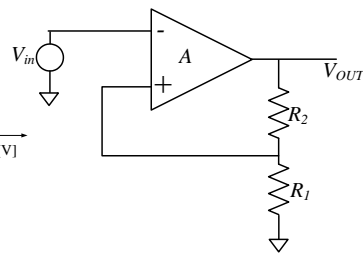


VTC with hysteresis

Inverting Schmitt Trigger

$$V_{TH} = \frac{R_1}{R_1 + R_2} V_{OH}$$

$$V_{TL} = \frac{R_1}{R_1 + R_2} V_{OL}$$



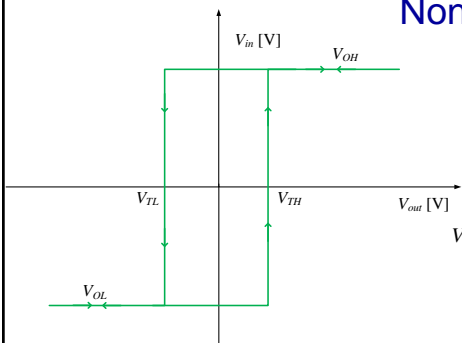
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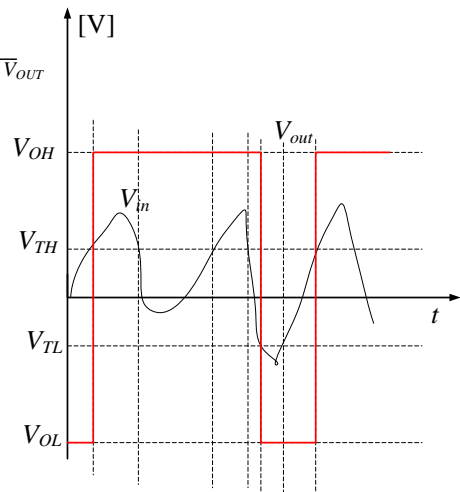
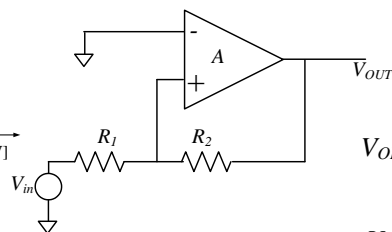
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## Non-inverting Schmitt Trigger



$$V_{TH} = -\frac{R_1}{R_2} V_{OL}$$

$$V_{TL} = -\frac{R_1}{R_2} V_{OH}$$





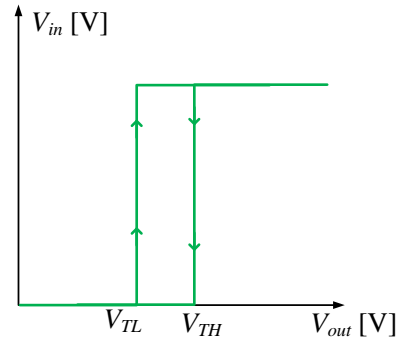
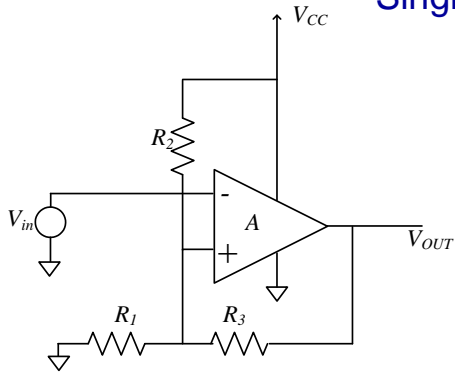
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## Single-supply Schmitt Trigger



$$V_{TH} = \frac{R_1}{R_1 + (R_2 || R_3)} V_{CC}$$

$$V_{TL} = \frac{R_1 || R_3}{R_2 + (R_1 || R_3)} V_{CC}$$



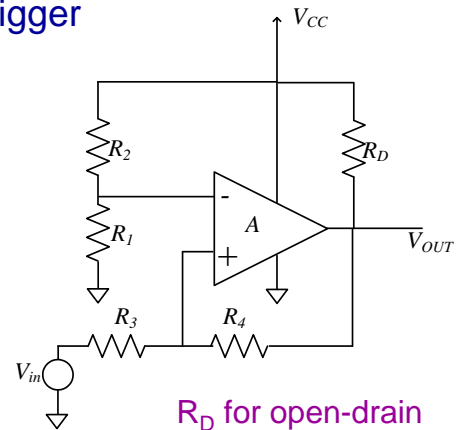
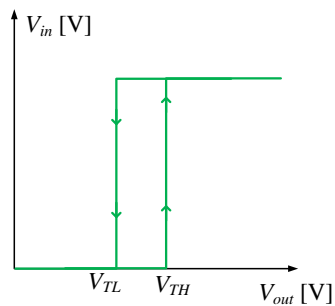
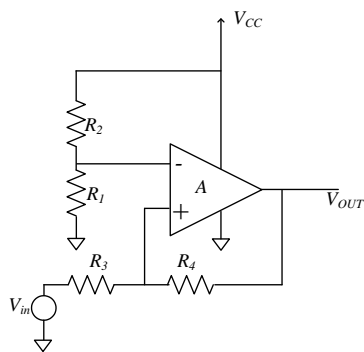
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## Single-supply Schmitt Trigger



$R_D$  for open-drain

$$\frac{R_1}{R_2} = \frac{V_{TH} - V_{TL}}{V_{CC}}$$

$$\frac{R_3}{R_4} = \frac{V_{CC} - V_{TL}}{V_{TH}}$$



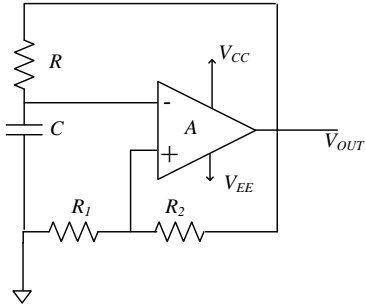
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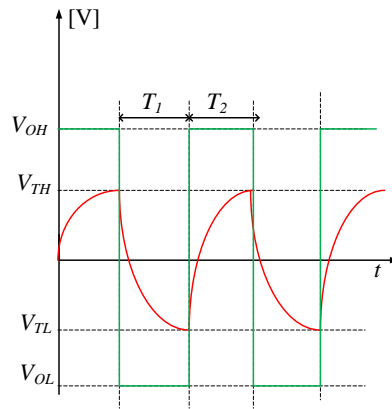
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## Oscillators



$$V_{TH} = \frac{R_1}{R_1 + R_2} V_{OH}$$

$$V_{TL} = \frac{R_1}{R_1 + R_2} V_{OL}$$



$$V(t) = V_{\infty} - (V_{\infty} - V_0)e^{-\frac{t}{\tau}}$$

$$T_1:$$

$$V_{\infty} = V_{EE}$$

$$V_0 = V_{TH}$$

$$V(t) = V_{TL}$$

$$T_2:$$

$$V_{\infty} = V_{CC}$$

$$V_0 = V_{TL}$$

$$V(t) = V_{TH}$$



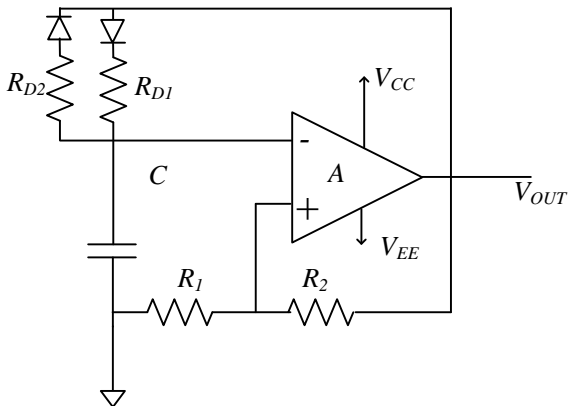
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## Oscillators programmed on/off





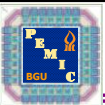
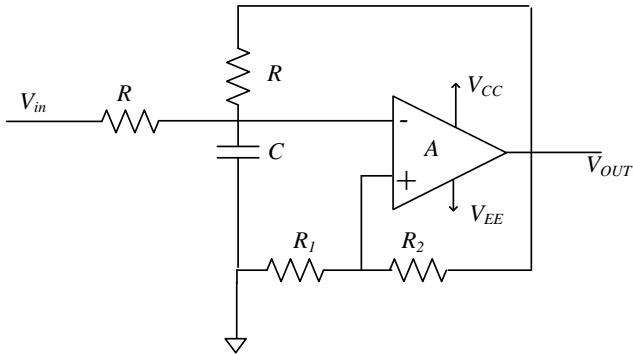
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## Voltage-Controlled Oscillator VCO



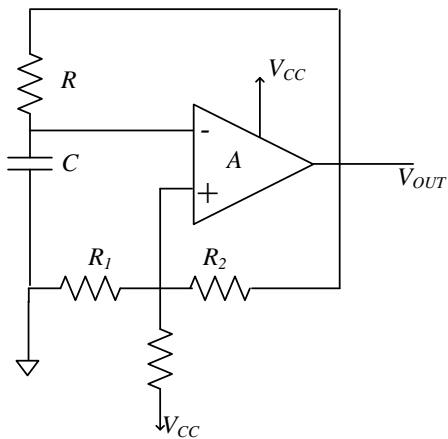
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## Oscillator Single supply





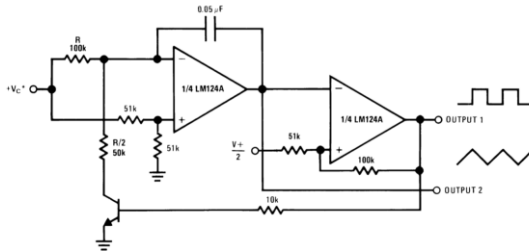
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## Voltage-Controlled Oscillator Programmable freq



\*Wide control voltage range:  
 $0 V_{DC} \leq V_C \leq 2 (V^+ - 1.5 V_{DC})$

Figure 33. Voltage Controlled Oscillator Circuit



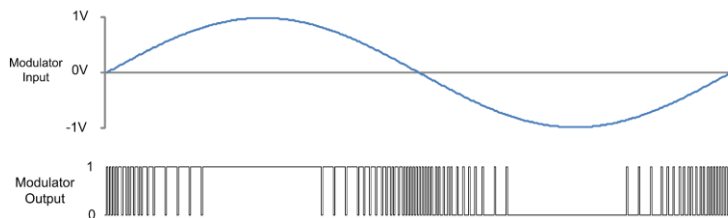
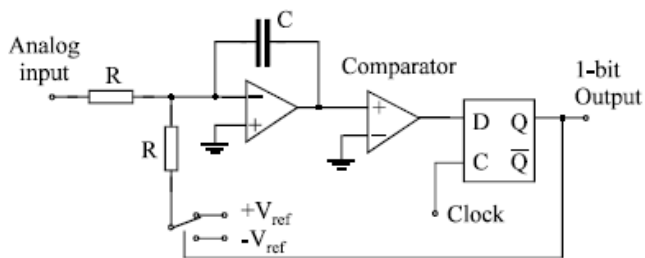
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## $\Sigma$ - $\Delta$ ADC





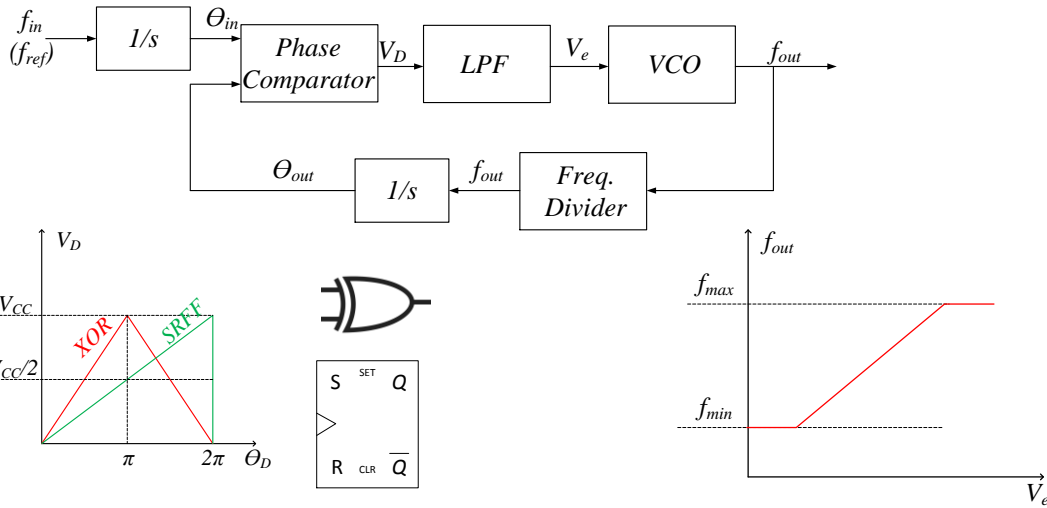
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## Phase-Locked-Loop PLL

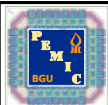


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