

Prof. Mor M. Peretz      Analog Electronic Circuits 361-1-3671      [1]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

---

**Analog Electronic Circuits**

Prof. Mor M. Peretz

The Center for Power Electronics and Mixed-Signal IC  
 Department of Electrical and Computer Engineering  
 Ben-Gurion University of the Negev, ISRAEL  
 Emails: [morp@bgu.ac.il](mailto:morp@bgu.ac.il)  
 Website: <http://www.ee.bgu.ac.il/~pemic>  
<http://www.ee.bgu.ac.il/~analog>

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz      Analog Electronic Circuits 361-1-3671      [2]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

---

**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

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz      Analog Electronic Circuits 361-1-3671      [3]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

---

**Comparator**

---

---

---

---

---

---

---

---



Prof. Mor M. Peretz Analog Electronic Circuits 361-1-3671 [7]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

### Output stage

Push-pull

Open-drain (Open-Collector)

---

---

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz Analog Electronic Circuits 361-1-3671 [8]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

### Basic operation

BASIC OPERATION OF VOLTAGE COMPARATORS  
 (OPERATION MODE)

CIRCUIT - A

CIRCUIT - B

http://home.cergec.ca/~gaurby/4E/notes/index.html

---

---

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz Analog Electronic Circuits 361-1-3671 [9]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

### Applications –basic

Figure 13. Zero-Crossing Detector

FIGURE 9.11 Basic level detector with optical indicator.

S. Franco

---

---

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz Analog Electronic Circuits 361-1-3671 [10]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

Applications –basic

PWM

S. Franco

---

---

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz Analog Electronic Circuits 361-1-3671 [11]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

Applications –basic

S. Franco

---

---

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz Analog Electronic Circuits 361-1-3671 [12]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

Comparator noise

S. Franco

---

---

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz      Analog Electronic Circuits 361-1-3671      [13]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

### Schmitt Triggers

VTC with hysteresis

Inverting Schmitt Trigger

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

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


---

---

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz      Analog Electronic Circuits 361-1-3671      [14]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

### Non-inverting Schmitt Trigger

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

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


---

---

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz      Analog Electronic Circuits 361-1-3671      [15]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

### Single-supply Schmitt Trigger

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

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


---

---

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz      Analog Electronic Circuits 361-1-3671      [16]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

### Single-supply Schmitt Trigger

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

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

$R_D$  for open-drain

---

---

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz      Analog Electronic Circuits 361-1-3671      [17]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

### Oscillators

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

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

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

$T_1:$   
 $V_{\infty} = V_{EE}$   
 $V_0 = V_{TH}$   
 $V(t) = V_{TL}$

$T_2:$   
 $V_{\infty} = V_{CC}$   
 $V_0 = V_{TL}$   
 $V(t) = V_{TH}$

---

---

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz      Analog Electronic Circuits 361-1-3671      [18]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

### Oscillators programmed on/off

---

---

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz      Analog Electronic Circuits 361-1-3671      [19]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

### Voltage-Controlled Oscillator VCO

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz      Analog Electronic Circuits 361-1-3671      [20]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

### Oscillator Single supply

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz      Analog Electronic Circuits 361-1-3671      [21]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

### Voltage-Controlled Oscillator Programmable freq

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

Figure 33. Voltage Controlled Oscillator Circuit

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz      Analog Electronic Circuits 361-1-3671      [22]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

### Σ-Δ ADC

---

---

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz      Analog Electronic Circuits 361-1-3671      [23]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

### Phase-Locked-Loop PLL

---

---

---

---

---

---

---

---

---

---

Prof. Mor M. Peretz      Analog Electronic Circuits 361-1-3671      [24]  
 THE CENTER FOR POWER ELECTRONICS AND MIXED-SIGNAL IC, BEN-GURION UNIVERSITY

---

---

---

---

---

---

---

---

---

---



---

---

---

---

---

---

---

---