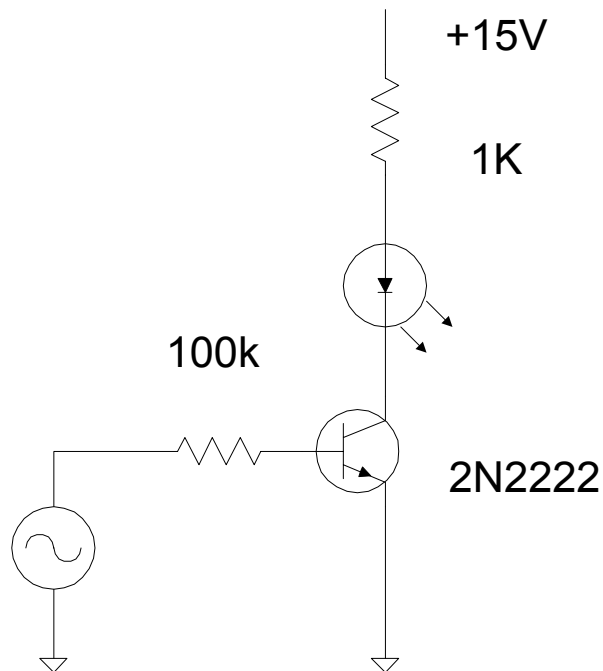
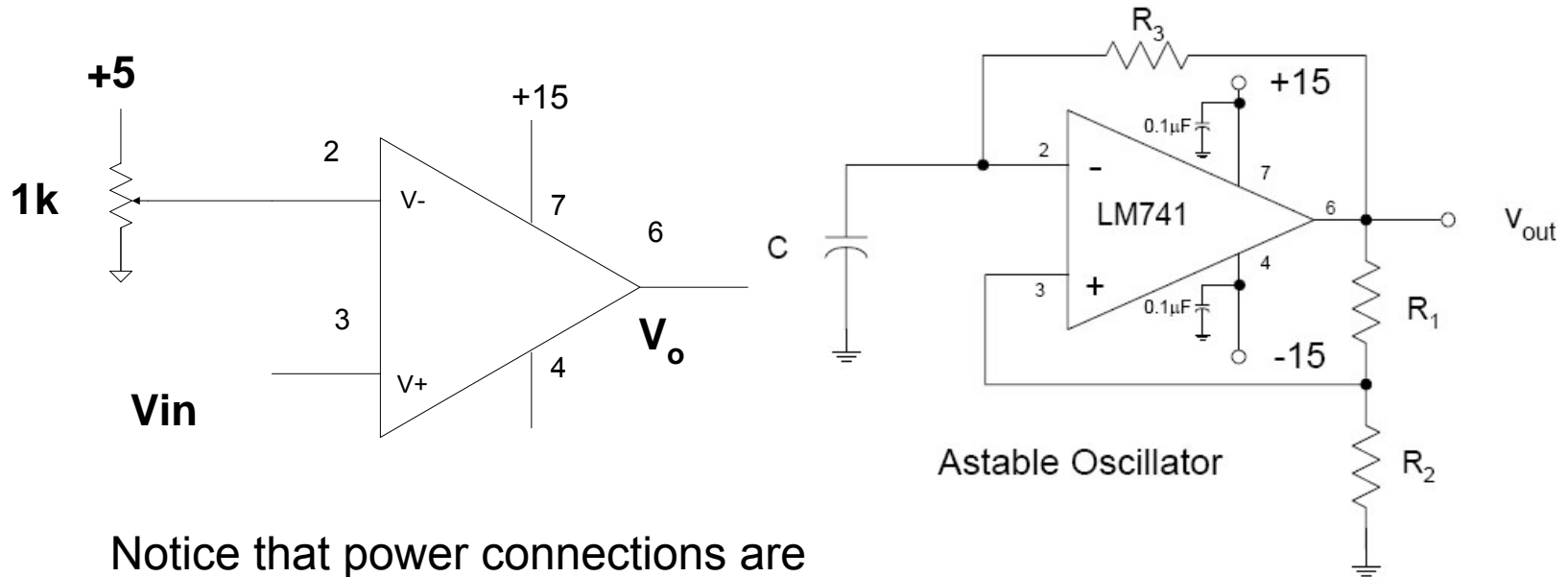


Lab 2 Revisited Exercise



- Wire up led display
- Note the ground leads
- LED orientation

Comparator, Oscillator

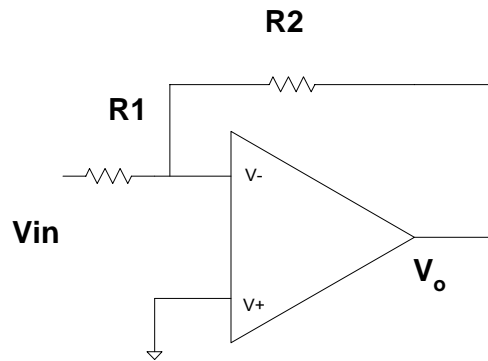


Notice that power connections are shown; bypass capacitors included for power supply filtering.

All voltage measurements are referenced to ground

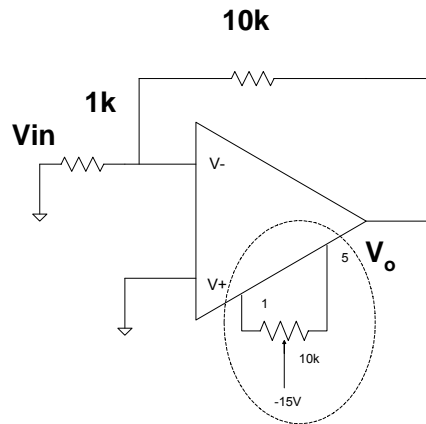
Op-Amps

Inverting Amplifier

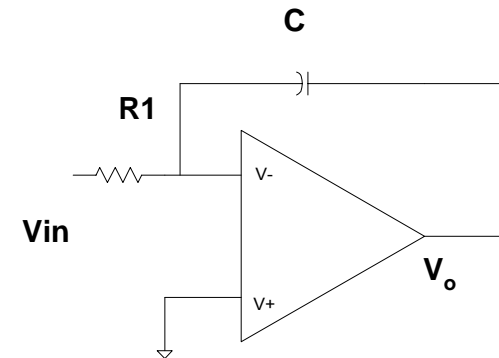


$$v_o = -\frac{R2}{R1} v_{in}$$

Null Adjustment



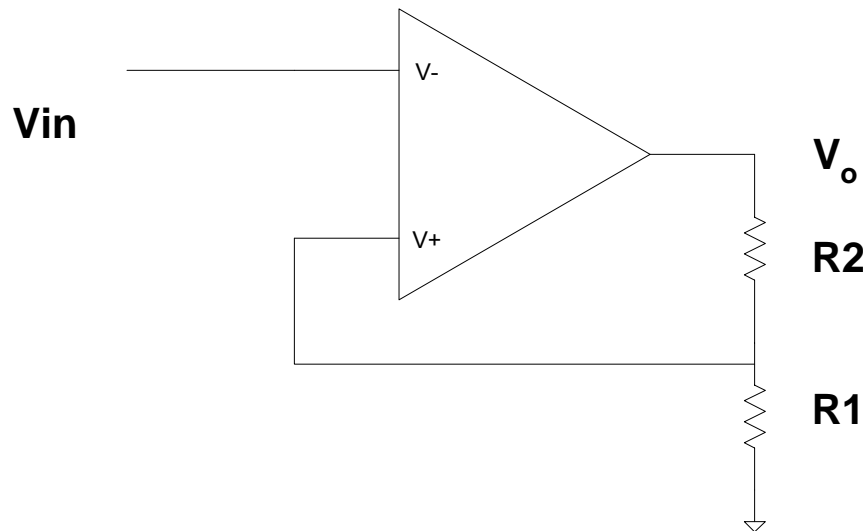
Integrator



$$v_o = -\frac{v_{in}}{RC} \int dt$$

For clarity, power connections and bypass capacitors not shown.

Lab Exercise - Schmitt Trigger



- Schmitt trigger have different triggers points for rising edge and falling edge.
- Can be used to reduce false triggering
- This is NOT a negative feedback circuit.

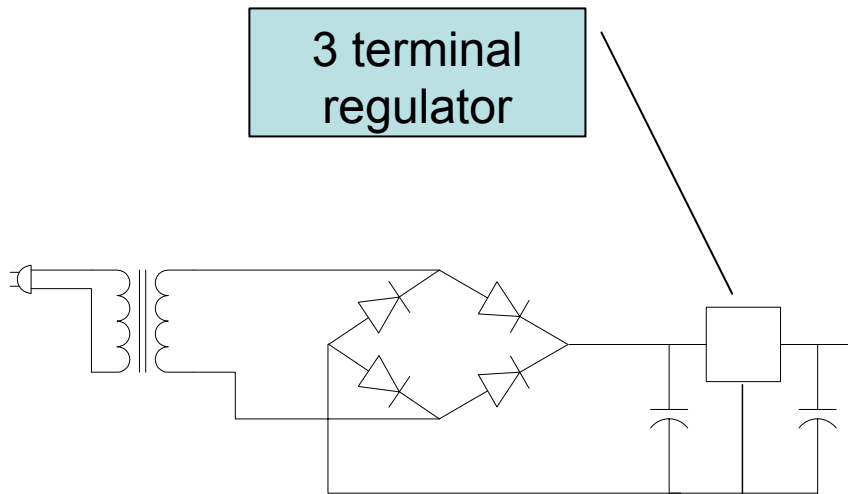
Notes

- IC power supply connections generally not drawn. All integrated circuits need power!
- Use standard color coded wires to avoid confusion.



Potentiometer
internals

Power Supplies, Voltage Regulators



- Conventional Power Supply
 - rectify (convert AC to DC)
 - filter out the ripple
 - regulate the voltage
- 3 terminal IC regulator

Wire Gauge

- Wire gauge: diameter is inversely proportional to the wire gauge number. Diameter increases as the wire gauge decreases. 2, 1, 0, 00, 000(3/0) up to 7/0.
- Resistance
 - 22 gauge .0254 in 16 ohm/1000 feet
 - 12 gauge .08 in 1.5 ohm/1000 feet
 - High voltage AC used to reduce loss

78XX Voltage Regulator



August 2005

+5V, +12V, +15V

-5V, -12V, -15V

LM340/LM78XX Series 3-Terminal Positive Regulators

General Description

The LM140/LM340A/LM340/LM78XXC monolithic 3-terminal positive voltage regulators employ internal current-limiting, thermal shutdown and safe-area compensation, making them essentially indestructible. If adequate heat sinking is provided, they can deliver over 1.0A output current. They are intended as fixed voltage regulators in a wide range of applications including local (on-card) regulation for elimination of noise and distribution problems associated with single-point regulation. In addition to use as fixed voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents.

Considerable effort was expended to make the entire series of regulators easy to use and minimize the number of external components. It is not necessary to bypass the output, although this does improve transient response. Input bypassing is needed only if the regulator is located far from the filter capacitor of the power supply.

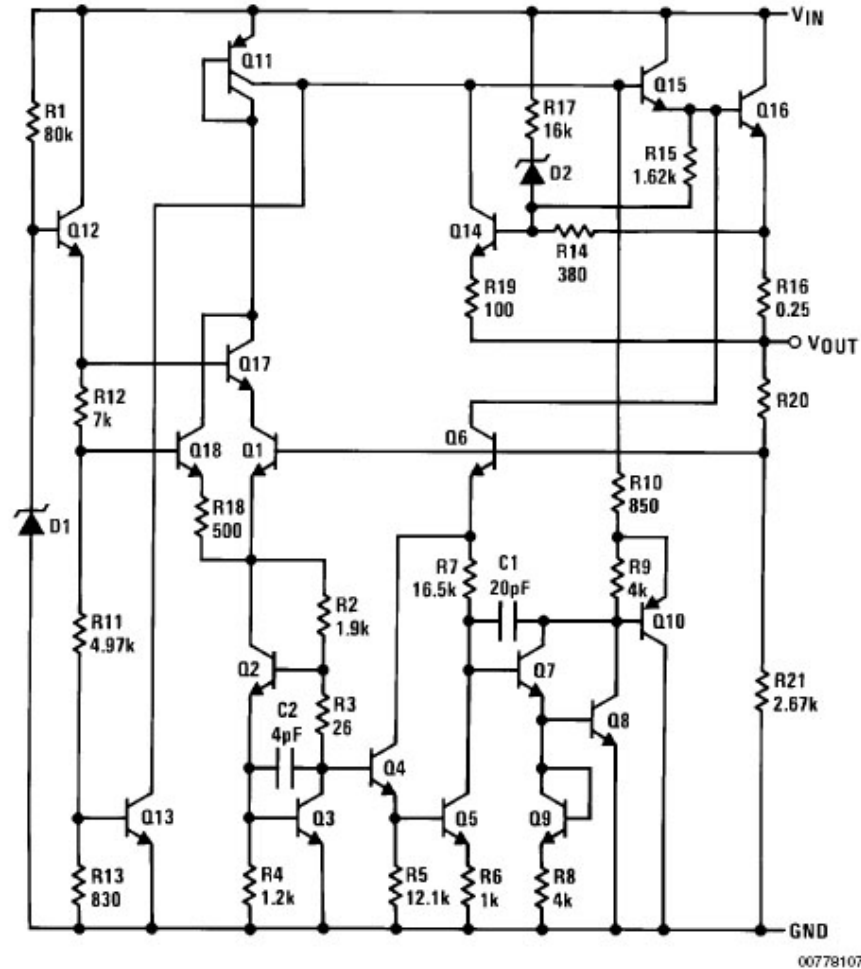
The 5V, 12V, and 15V regulator options are available in the steel TO-3 power package. The LM340A/LM340/LM78XXC series is available in the TO-220 plastic power package, and the LM340-5.0 is available in the SOT-223 package, as well as the LM340-5.0 and LM340-12 in the surface-mount TO-263 package.

Features

- Complete specifications at 1A load
- Output voltage tolerances of $\pm 2\%$ at $T_j = 25^\circ\text{C}$ and $\pm 4\%$ over the temperature range (LM340A)
- Line regulation of 0.01% of V_{OUT}/V of ΔV_{IN} at 1A load (LM340A)
- Load regulation of 0.3% of V_{OUT}/A (LM340A)
- Internal thermal overload protection
- Internal short-circuit current limit
- Output transistor safe area protection
- P+ Product Enhancement tested

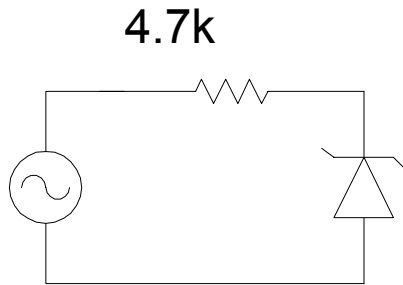
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7805 Circuit



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Zener Diode

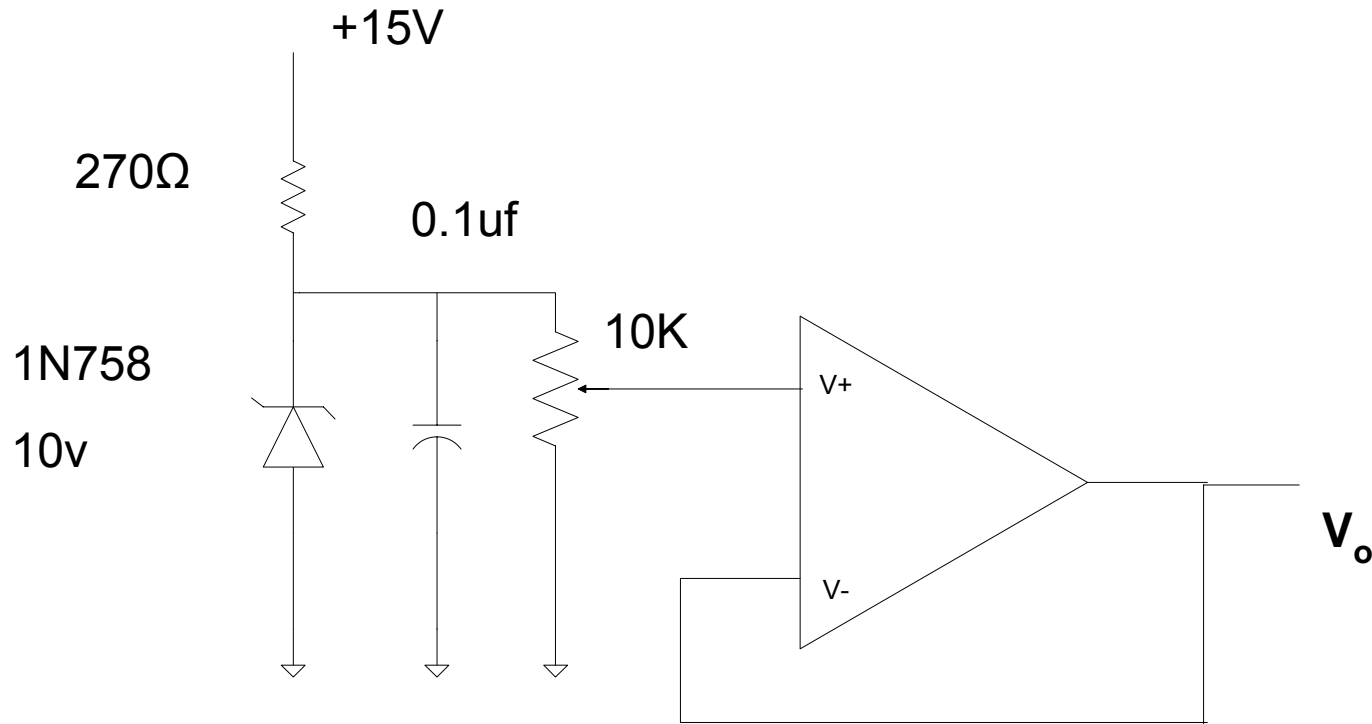


- Zener diodes will maintain a fixed voltage by breaking down at a predefined voltage (zener voltage).

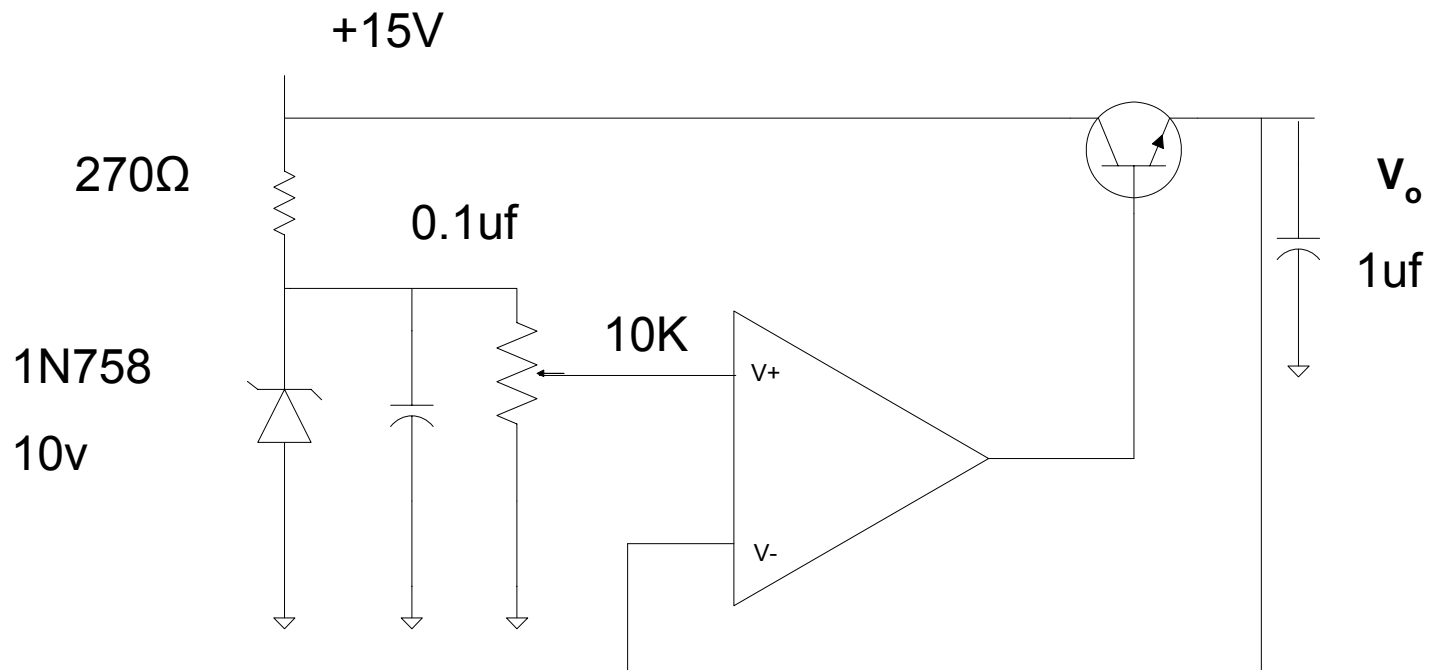
Lab exercise

- Wire up the above circuit with a 1N752A (5.6V) zener.
- Set the FG for a 0-10V ramp. Display the output of the FG and the voltage across the zener on the oscilloscope. Describe what is happening.

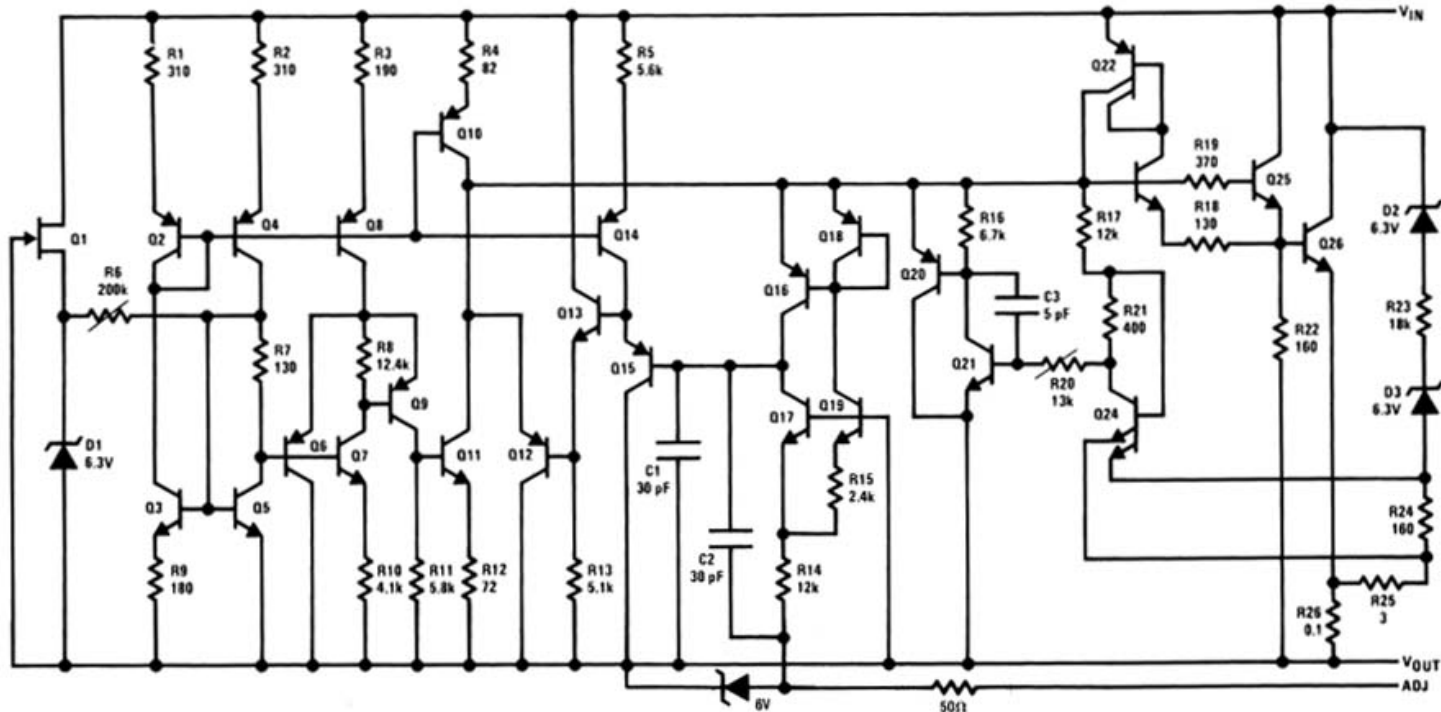
Adjustable Voltage Source



Adjustable Voltage Power Supply



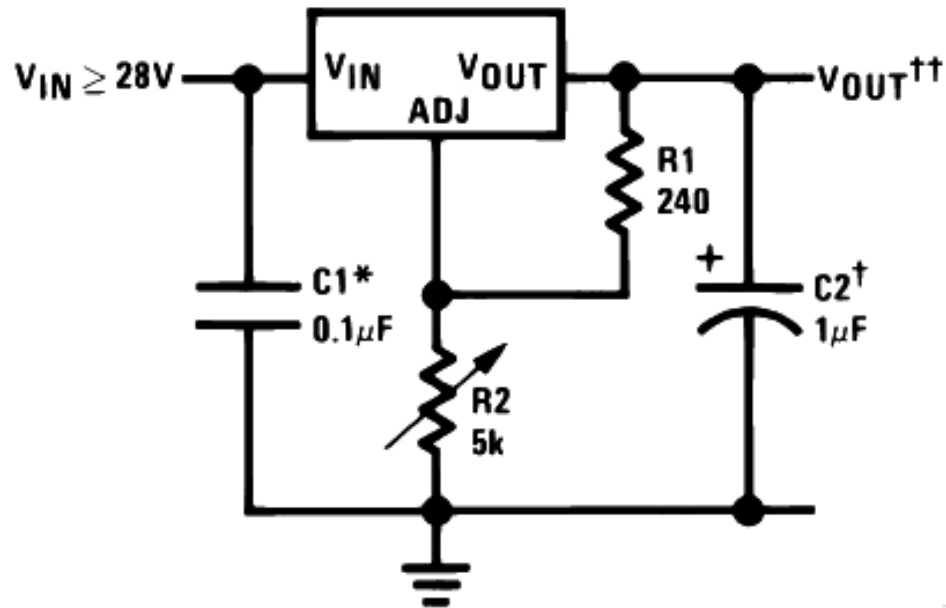
LM317 Three Terminator Adjustable Voltage Regulator



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- First 3 terminal adjustable voltage regulator
- 1.2 - 25 Voltage output range
- Short circuit protected
- Thermal shutdown

LM317



*Needed if device is more than 6 inches from filter capacitors.

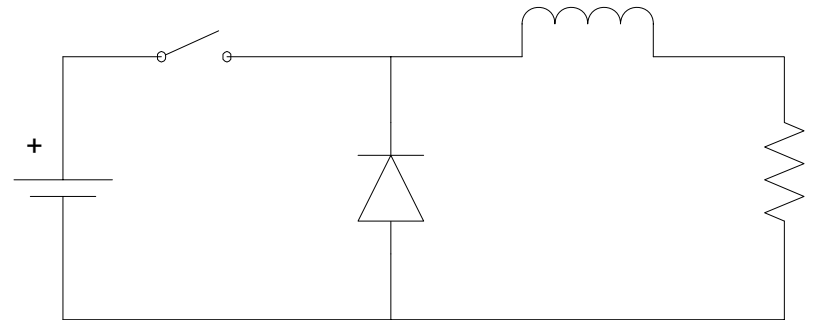
†Optional—improves transient response. Output capacitors in the range of 1μF to 1000μF of aluminum or tantalum electrolytic are commonly used to provide improved output impedance and rejection of transients.

$$\dagger\dagger V_{OUT} = 1.25V \left(1 + \frac{R2}{R1} \right) + I_{ADJ}(R2)$$

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Buck Converters

- Linear power supplies are very inefficient
- Power dissipated by regulating element
- Buck converters operating in switching mode (on/off)



555 Timers

- Simple, versatile, low cost IC for timing applications: oscillators, one-shot pulse generator, pulse width modulator, missing pulse detector
- Circuit: two comparators, flip flop, resistor divider and a discharge transistor.

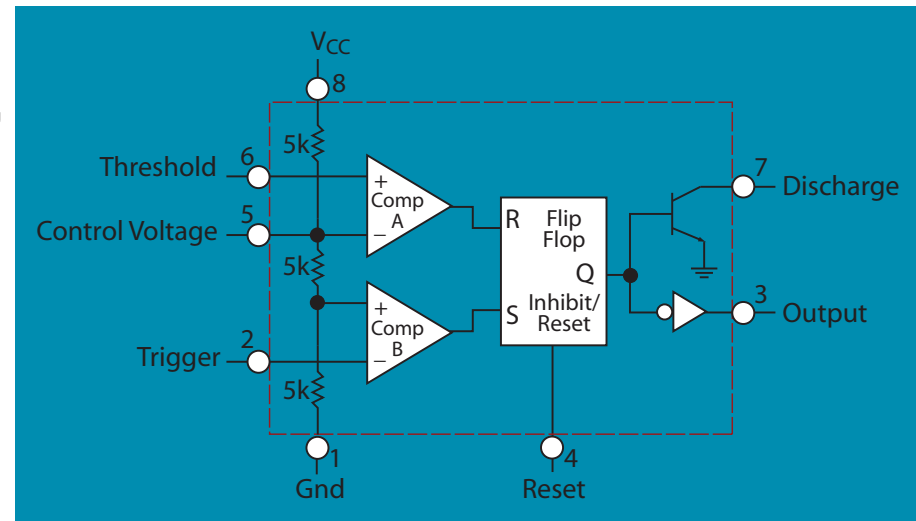


Figure by MIT OpenCourseWare.

555 Block Diagram

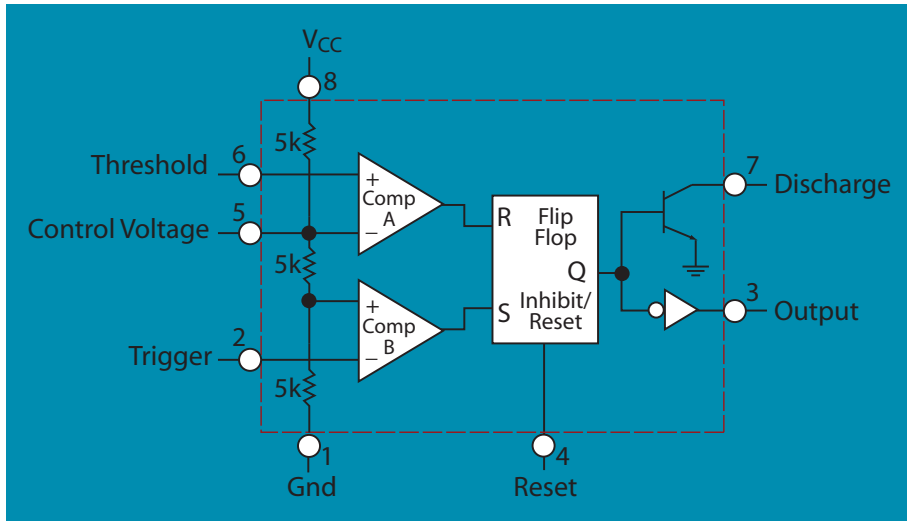
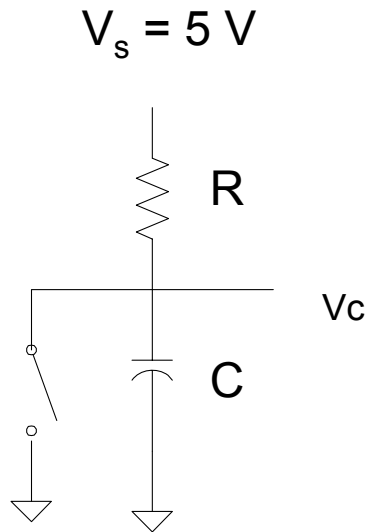


Figure by MIT OpenCourseWare.

S	R	Reset	Output
1	1	1	last state
0	1	1	low
1	0	1	high
0	0	1	high
NA	NA	0	low

RC Equation



$$V_c = 5 \left(1 - e^{-\frac{t}{RC}} \right)$$

$$V_s = 5\text{ V}$$

Switch is closed $t < 0$

Switch opens $t > 0$

$$V_s = V_R + V_C$$

$$V_s = i_R R + V_C \quad i_R = C \frac{dV_c}{dt}$$

$$V_s = RC \frac{dV_c}{dt} + V_c$$

$$V_c = V_s \left(1 - e^{-\frac{t}{RC}} \right)$$

Monostable Circuit

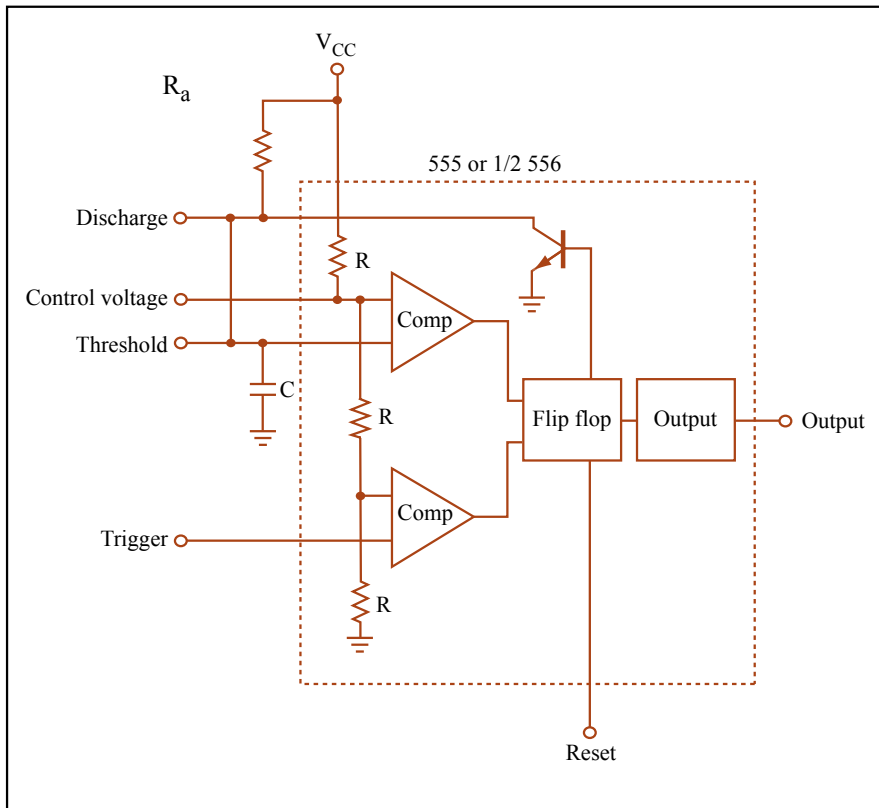
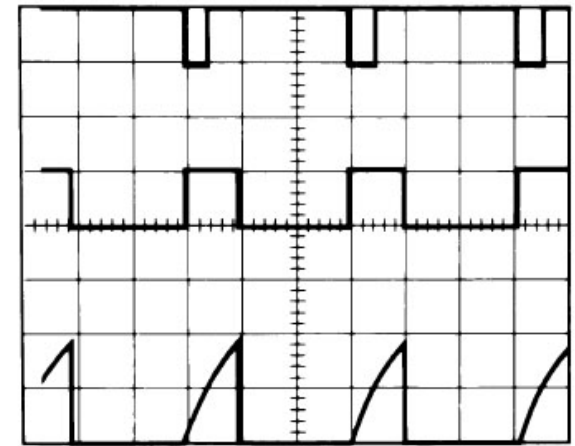


Figure by MIT OpenCourseWare,
based on Philips Semiconductors datasheet.



DS007851-6

$V_{CC} = 5V$
 TIME = 0.1 ms/DIV.
 $R_A = 9.1k\Omega$
 $C = 0.01\mu F$

Top Trace: Input 5V/Div.
 Middle Trace: Output 5V/Div.
 Bottom Trace: Capacitor Voltage 2V/Div.

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Oscillator (Astable)

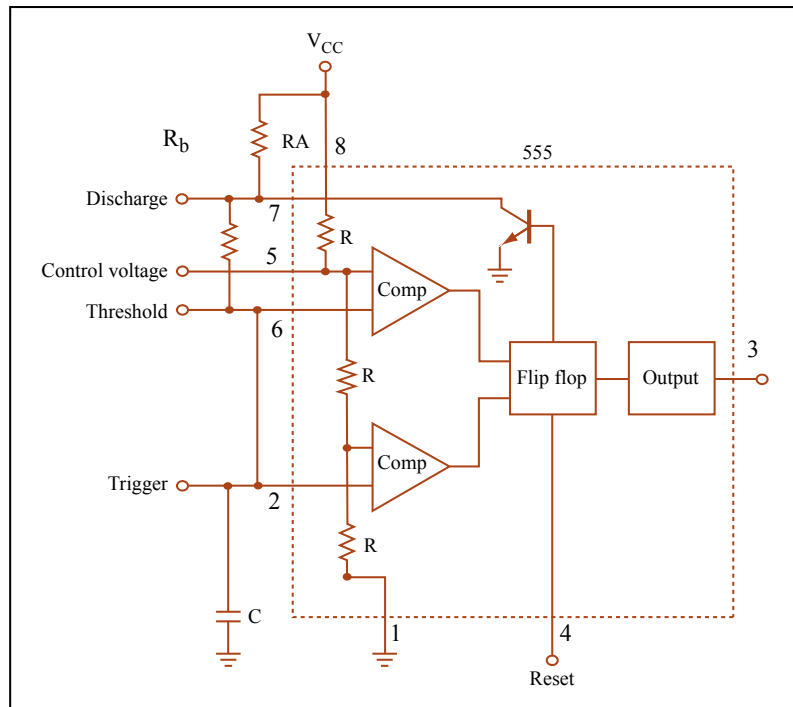
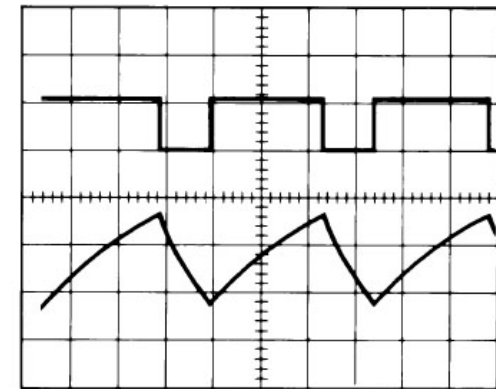


Figure by MIT OpenCourseWare,
based on Philips Semiconductors datasheet.



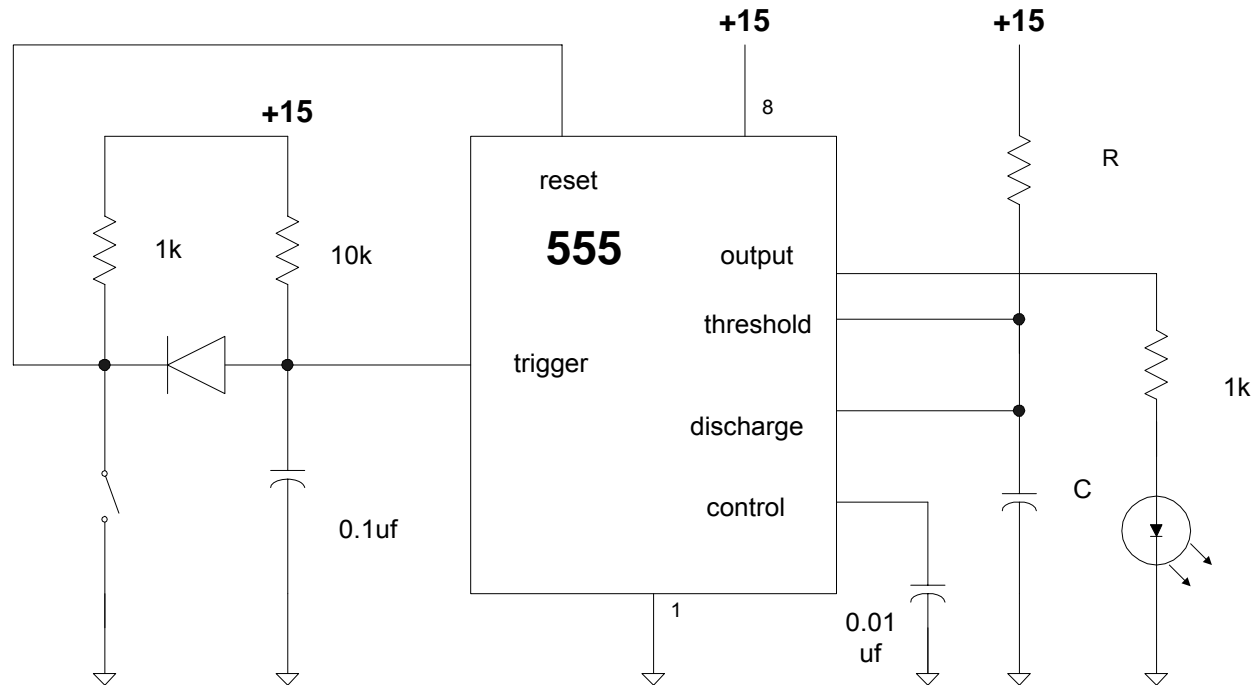
DS007851-9

$V_{CC} = 5V$
TIME = 20 μ s/DIV.
 $R_A = 3.9k\Omega$
 $R_B = 3k\Omega$
 $C = 0.01\mu F$

Top Trace: Output 5V/Div.
Bottom Trace: Capacitor Voltage 1V/Div.

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Closet Light Timer – Lab Exercise



$$t_{on} = 1.1RC$$

Switch closed = door closed

Lab Exercise

- Wire up zener diode circuit
- Build variable voltage power supply
- Build variable current source
- Build 555 oscillator
- Build closet light timer

Analog Circuit Summary

- 3 Terminal Regulators
- Zener Diodes
- Power Supplies
- 555 Timers & circuits

Important Missing Links

- The real world is an analog world.
However, computing is best performed via digital systems (i.e. the processing of data with 0's and 1's).
- Digital-Analog Conversion
- Analog-Digital Conversion

Analog vs Digital

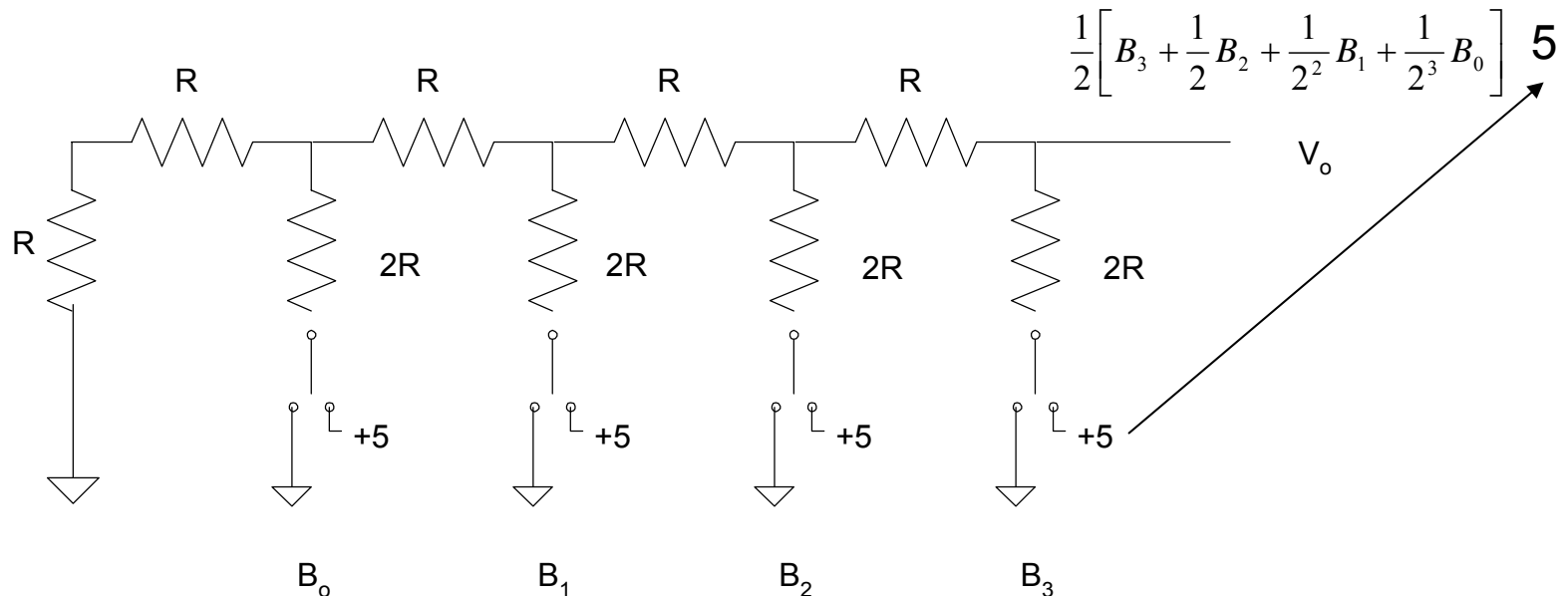
- Analog systems/devices work with information in a continuous stream: clock with hands, mercury thermometer, vinyl records, analog meters, calipers.
- Digital systems/devices work with information in a discontinuous stream (0,1): digital thermometer, digital meters, computers.

Music – An Example

- CD's are digital systems that sample and stores audio data
 - sampling rate: 44.1 khz
 - data stored in 16 bit format; implies $2^{16} = 65,536$ possible output levels
- DVD Audio samples at 96-192kHz/24 bits
- Analog records have an infinite number of output levels.

D-A Conversion (DAC)

- Problem: take a digital signal and convert to an analog voltage: R-2R ladder
0001 -> $1/16 * 5$ volt
0010 -> $2/16 * 5$ volt
0011 -> $3/16 * 5$ volt
⋮
1101 -> $14/16 * 5$ volt
1111 -> $15/16 * 5$ volt
- Note that the outputs are at discrete levels – not continuous!



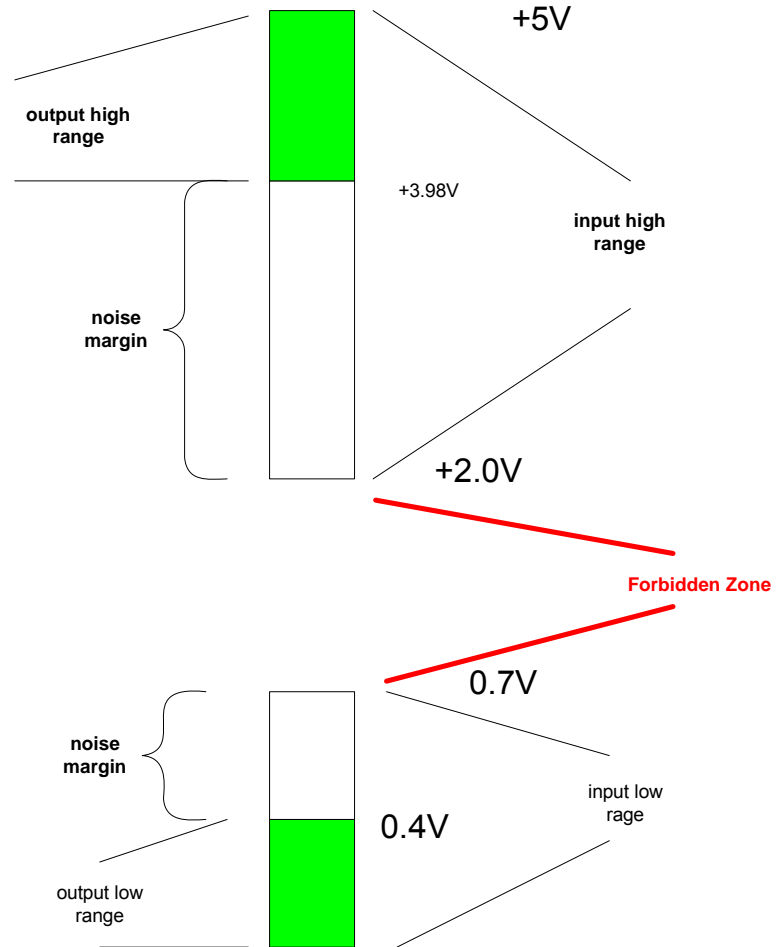
Digital Circuits

- Real world analog signals have noise – unavoidable.
- Digital circuits offers better noise immunity.
- Use voltage to represent “0” and “1”
 - Avoid forbidden voltage zone.
 - Make standards tighter for output than for inputs.
- Data (HCMOS family): 0 (low), 1 (high)
 - Input voltage low: **0.0 – 0.7v**
 - Input voltage high: **>2.0V**
 - Output low: **<0.4v**
 - Output high: **>3.98v**

Digital Circuits

HCMOS 1 (high)

- **Output high: $>3.98\text{v}$**
- Input voltage high: $>2.0\text{V}$



HCMOS 0 (low)

- **Output low: $<0.4\text{v}$**
- Input voltage low: $0.0 - 0.7\text{v}$

Power Requirements

- The following power supplies are common for analog and digital circuits:
 - +5v for digital circuits,
 - +15v, -15v for analog,
 - 5v, +12v, -12v also used
- Other voltages generally derived.

Boolean Algebra

$$A B = A \& B$$

$$\overline{A} = \text{Inverse of } A$$

$$\overline{A B} = \text{Inverse of } [A\&B]$$

DeMorgan's Law

$$\overline{A B} = \overline{A} + \overline{B}$$

$$\overline{A + B} = \overline{A} \& \overline{B}$$

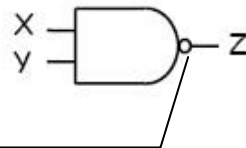
Digital System Implementation

- Start with AND, OR, NOR, NAND gates and add more complex building blocks: registers, counters, shift registers, multiplexers. Wire up design. High manufacturing cost, low fix costs. **Examples 74LS, 74HC series IC**
- For volume production, move to PALs, FPGAs, ASICs. Low manufacturing cost, high fix costs.

Basic Gates

Gate **Symbol** **Truth-Table** **Expression**

NAND



X	Y	Z
0	0	1
0	1	1
1	0	1
1	1	0

$$Z = \overline{X \cdot Y}$$

Circle indicates inversion

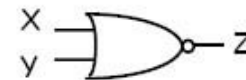
AND



X	Y	Z
0	0	0
0	1	0
1	0	0
1	1	1

$$Z = X \cdot Y$$

NOR



X	Y	Z
0	0	1
0	1	0
1	0	0
1	1	0

$$Z = \overline{X + Y}$$

OR

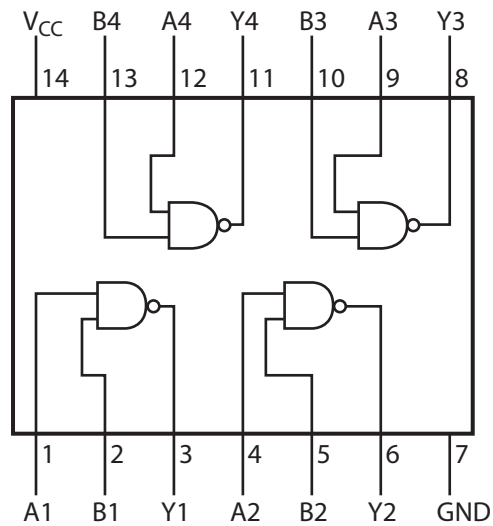


X	Y	Z
0	0	0
0	1	1
1	0	1
1	1	1

$$Z = X + Y$$

74LS00 NAND Gate

Dual-In-Line Package

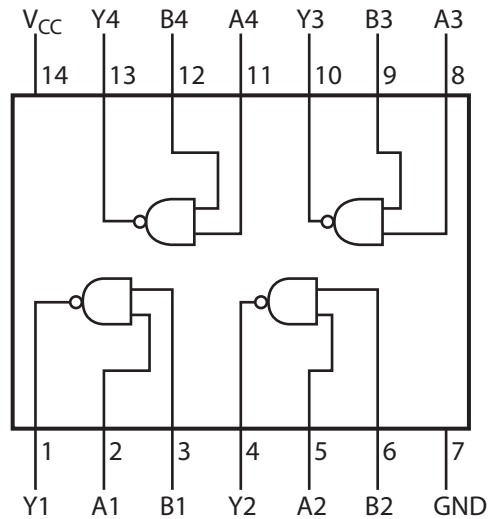


This device contains four independent gates each of which performs the logic NAND function.

Figure by MIT OpenCourseWare, adapted from the National Semiconductor 54LS00 datasheet.

74LS02 NOR Gate

Dual-In-Line Package

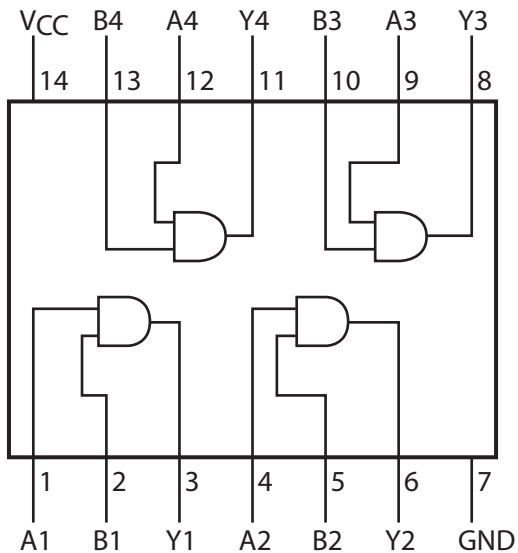


This device contains four independent gates each of which performs the logic NOR function.

Figure by MIT OpenCourseWare, adapted from the National Semiconductor 54LS02 datasheet.

74LS08 AND Gate

Dual-In-Line Package

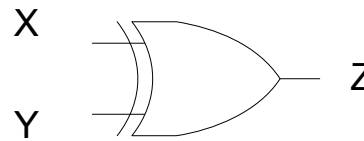


This device contains four independent gates each of which performs the logic AND function.

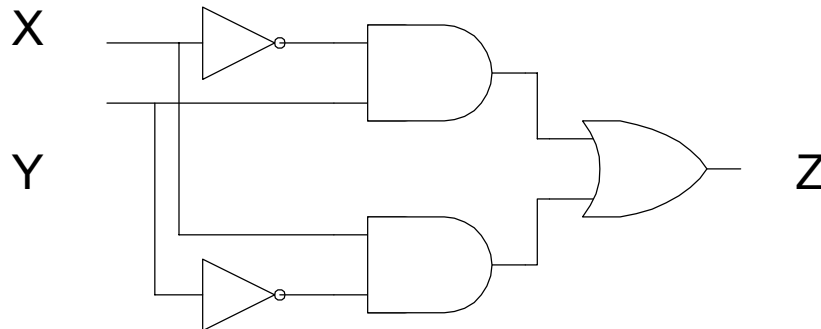
Figure by MIT OpenCourseWare, adapted from the National Semiconductor 54LS08 datasheet.

Building Logic

- From basic gates, we can build other functions: Exclusive OR Gate



X	Y	Z
0	0	0
0	1	1
1	0	1
1	1	0



74LS86 Exclusive OR

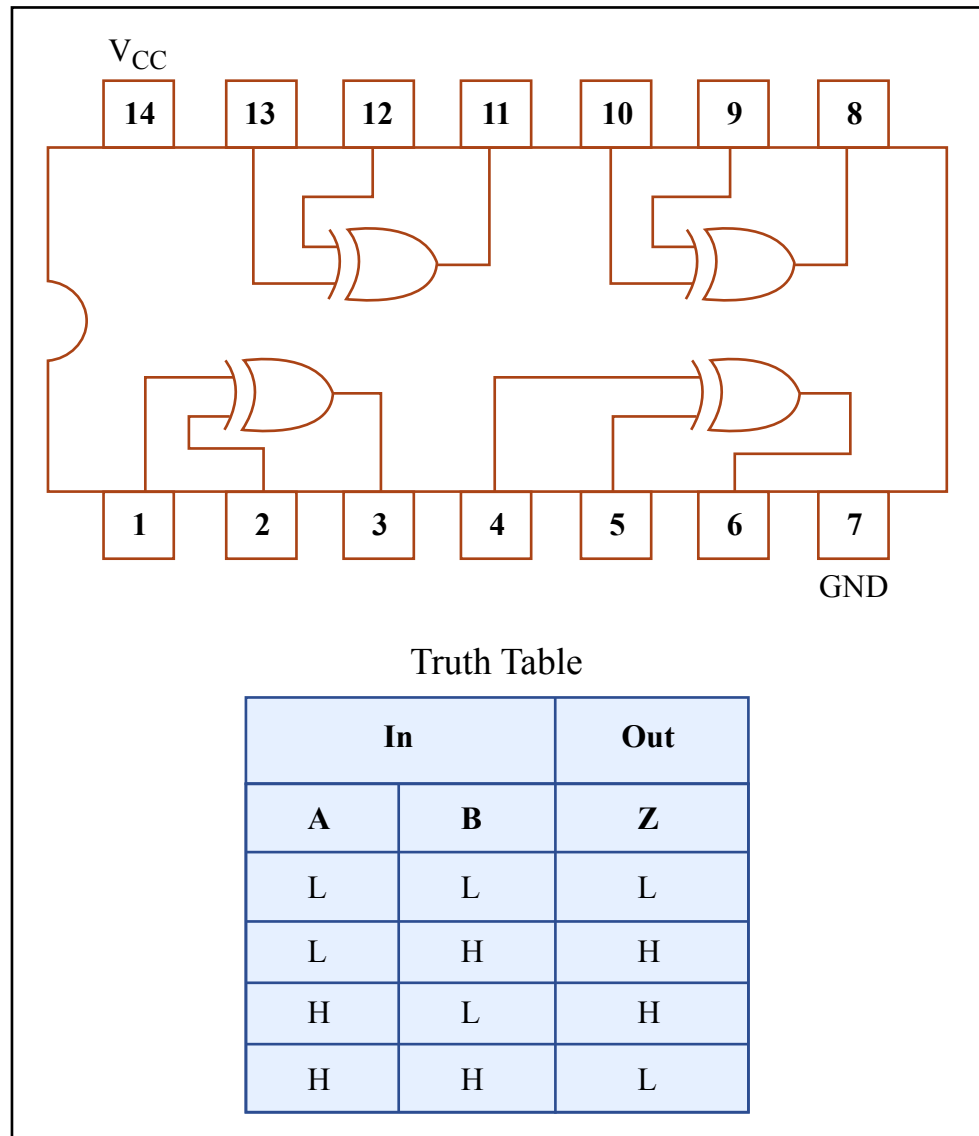


Figure by MIT OpenCourseWare, based on Motorola datasheet.