Electronics
Controlling Power to Output Transducers

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November 10, 2016

Basic Rule of Control

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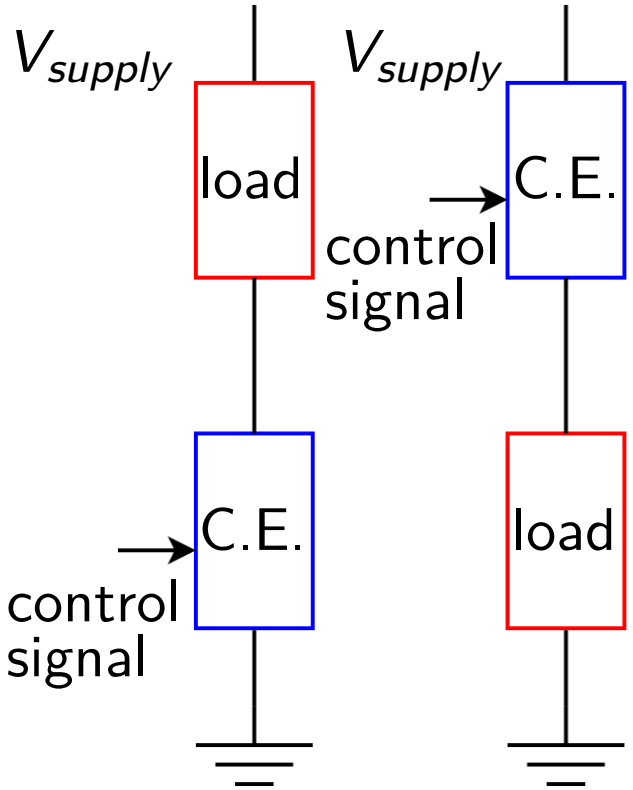
These will be arranged in a voltage divider.


V_{supply}
load
C.E.
control
signal
V_{supply}
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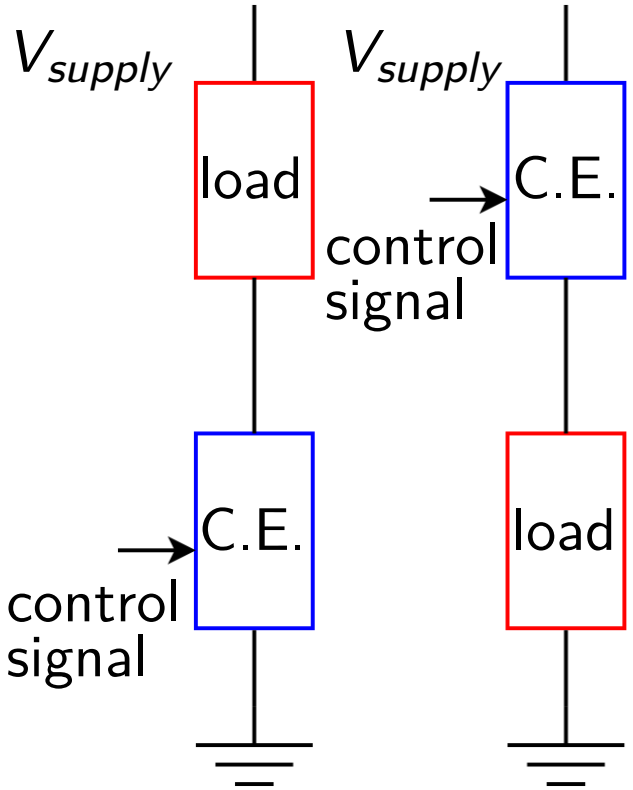
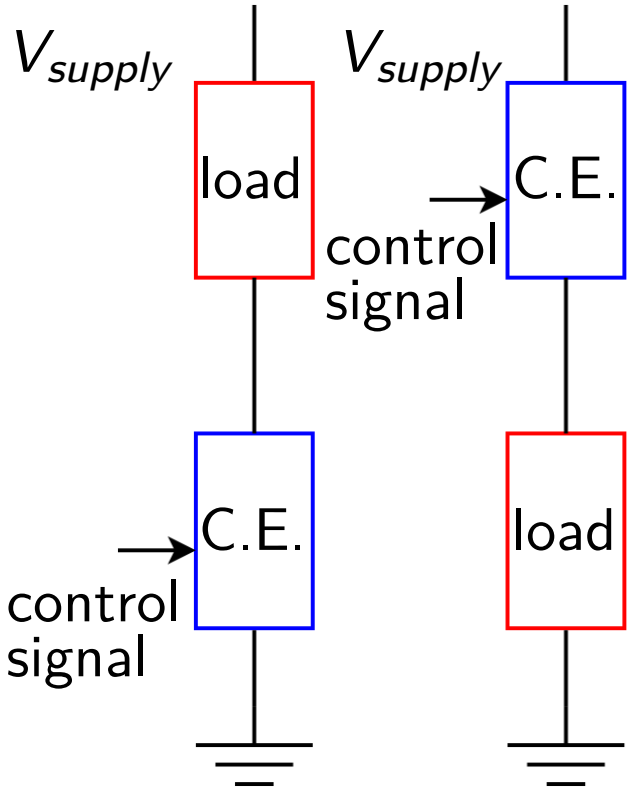


"C.E." is the control element.



"C.E." is the control element.

"Load" could be a motor, solenoid, relay coil, etc.

Low power devices

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These devices require *low power*.

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An operational amplifier is a *voltage* device; it can't produce more than a few mW of power.

Types of control

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- on/off

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  like a switch

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- proportional

Types of control

- on/off

  like a switch
- proportional

  like a rheostat or potentiometer

Control trade-offs

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There is a trade-off between efficiency and noise.

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- The order of the control element and the load in the voltage divider has some effects on the circuit operation.

Relay

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- coil

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- **NO**; normally open (possibly)

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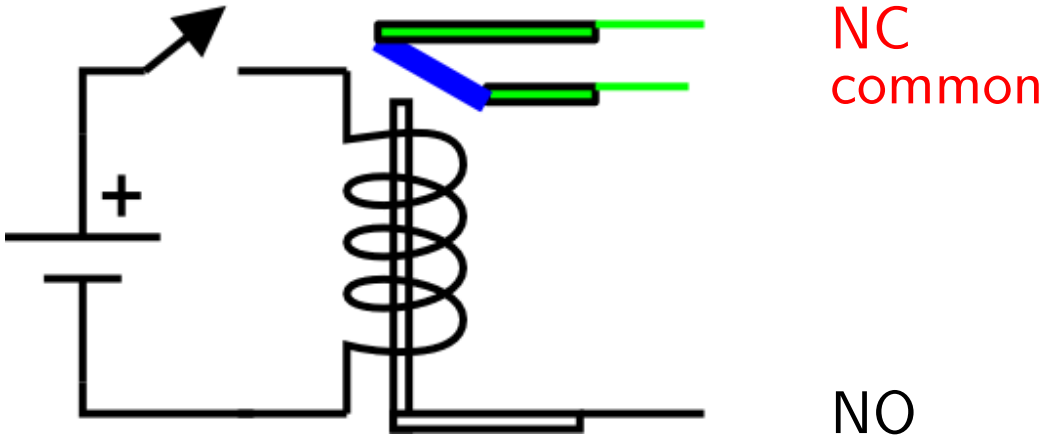
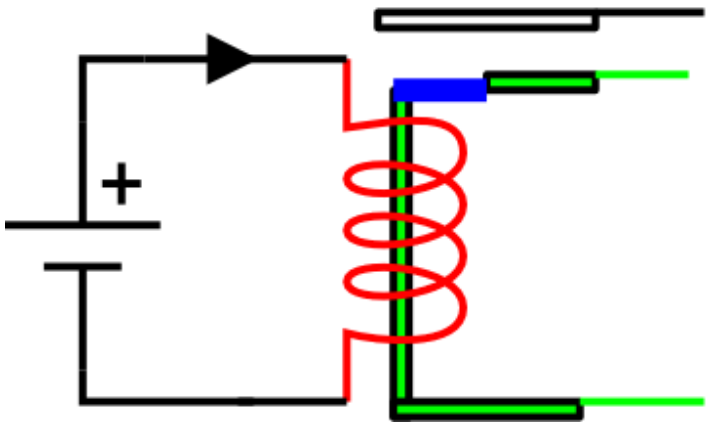
- coil
- common
- **NO**; normally open (possibly)
- **NC**; normally closed (possibly)

Relay **OFF**



Relay ON



NC
common

NO

An internal spring returns the solenoid to its original position when power is removed from the coil.

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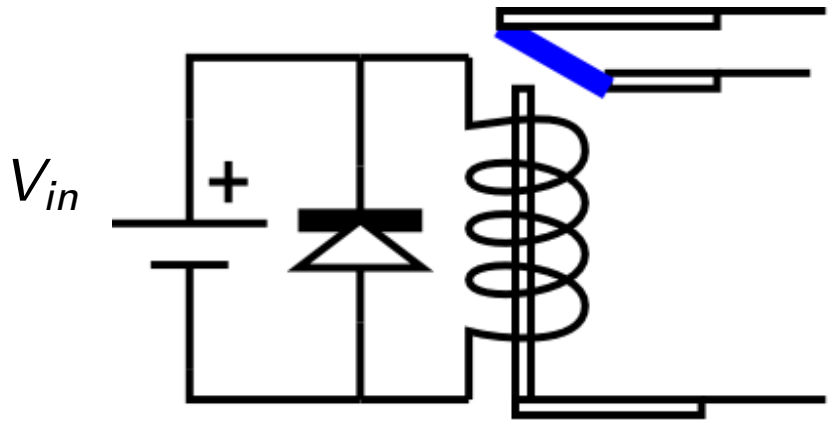

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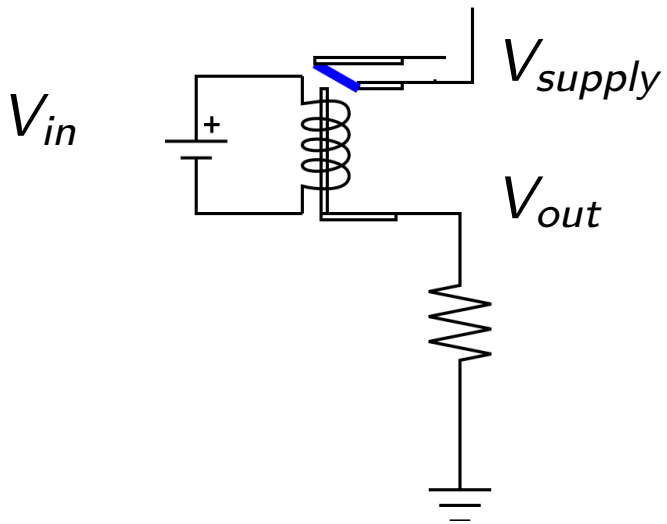

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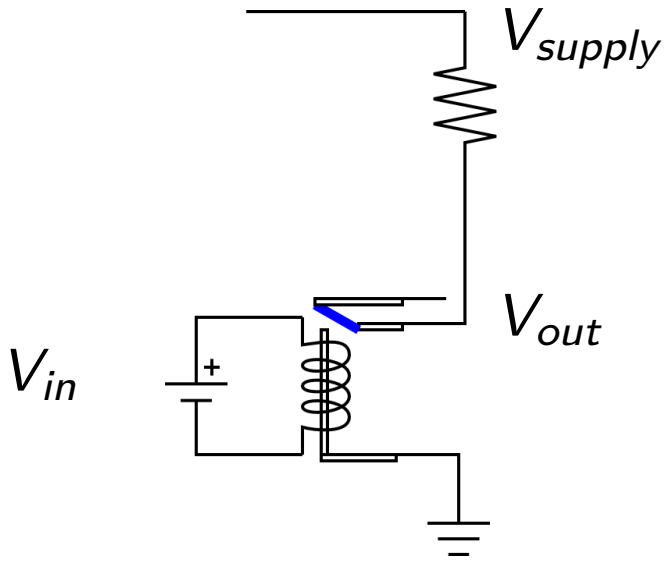

Transistors

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- Transistors are often used in voltage dividers to act as variable resistors.

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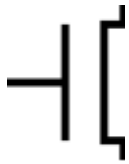
- gate

FET symbol



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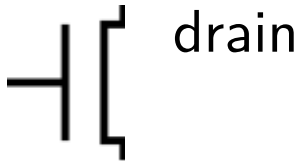

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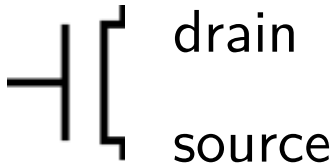

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Actually it's the voltage between the gate and the source which matters.

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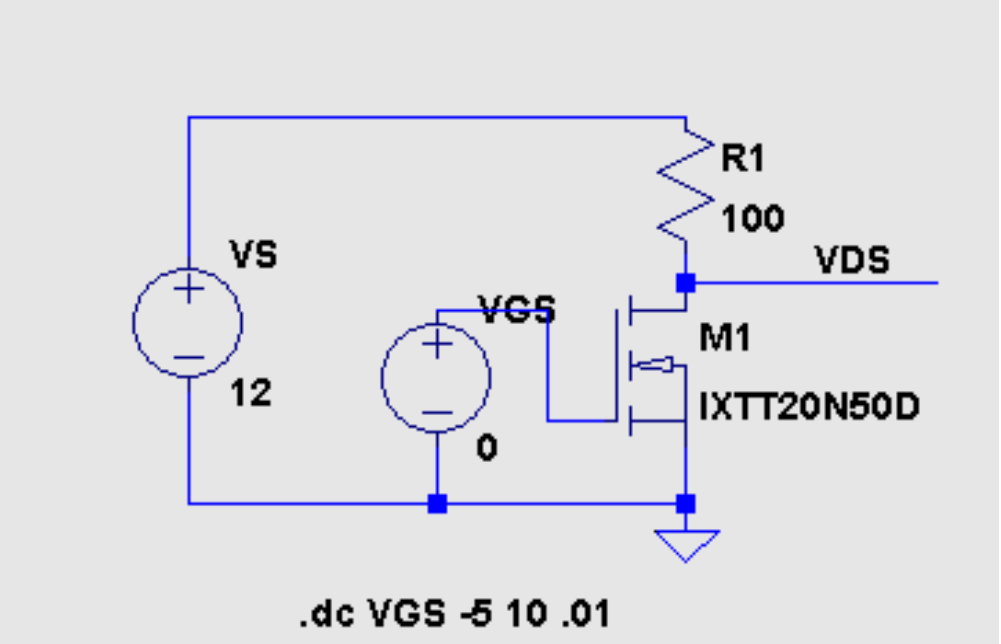
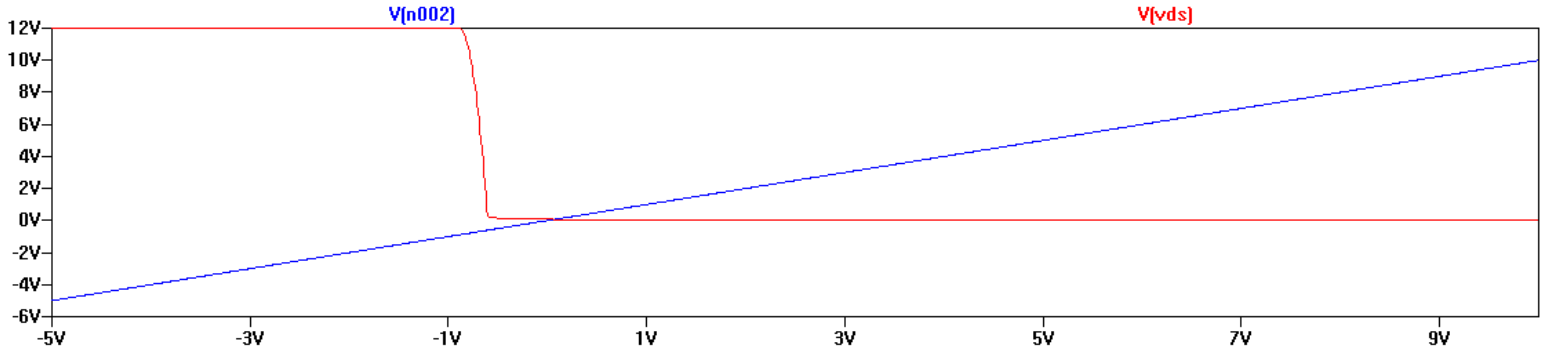
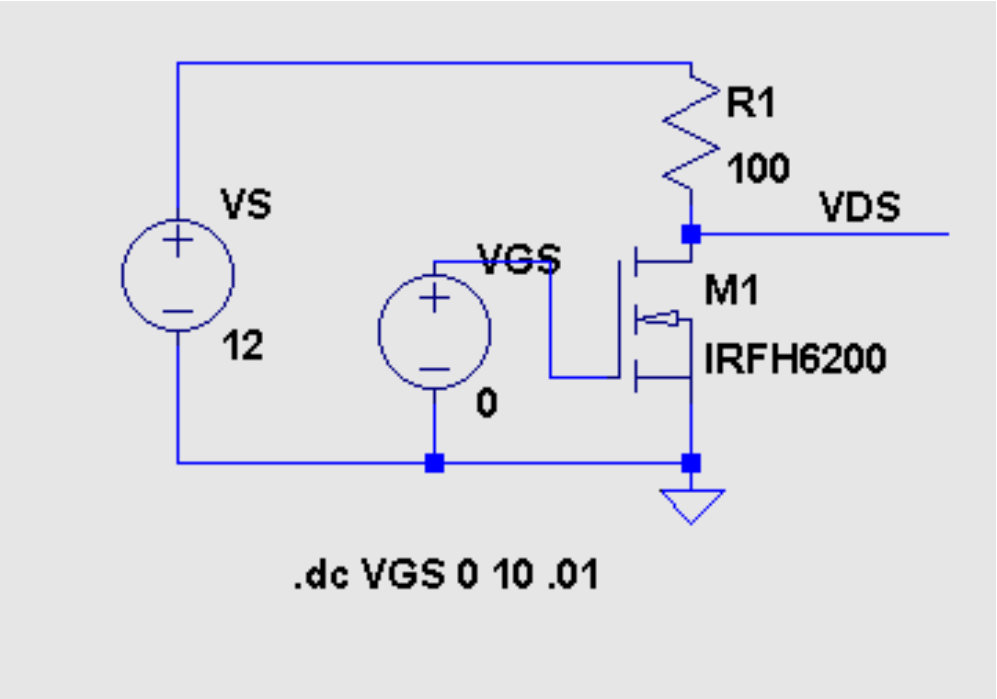


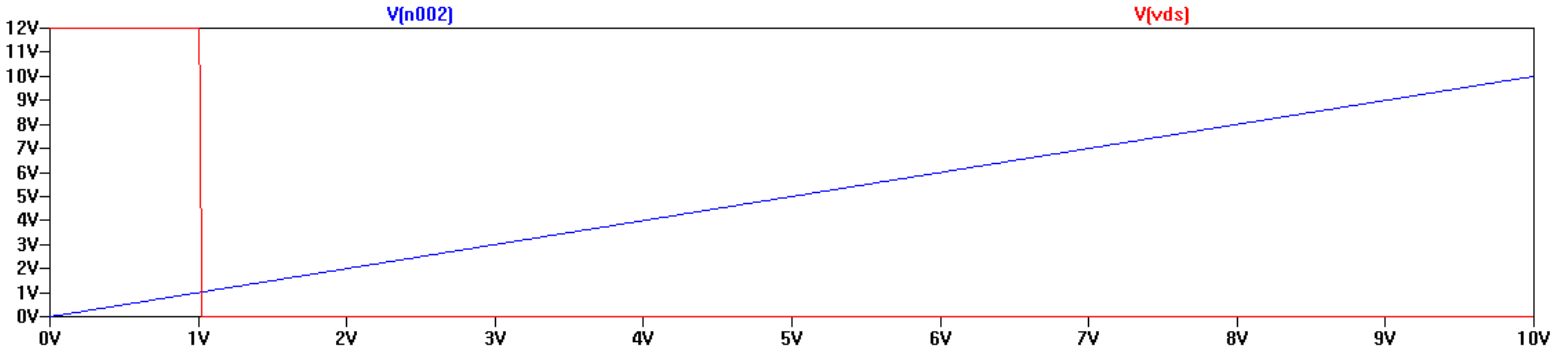
D (depletion mode) MOSFET



D (depletion mode) MOSFET output



E (enhancement mode) MOSFET



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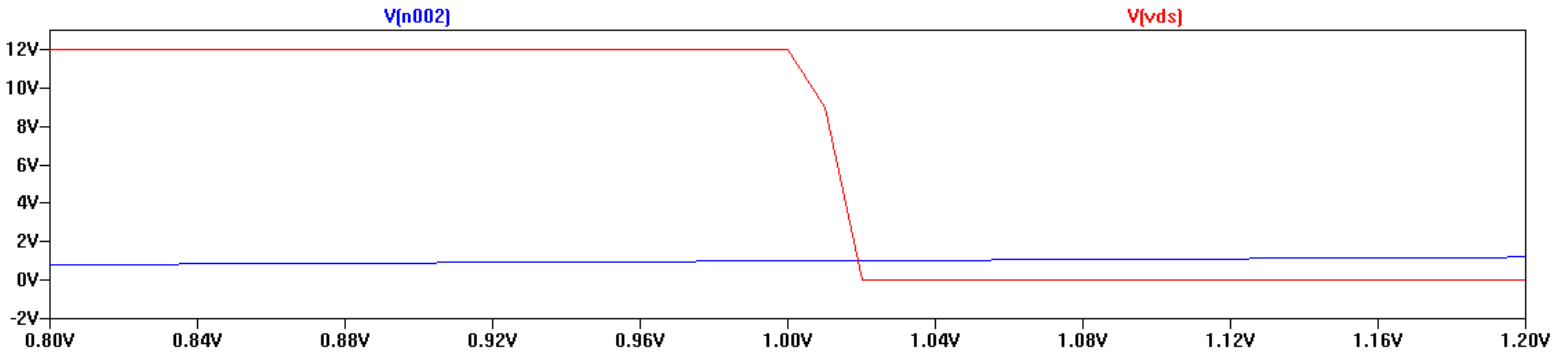
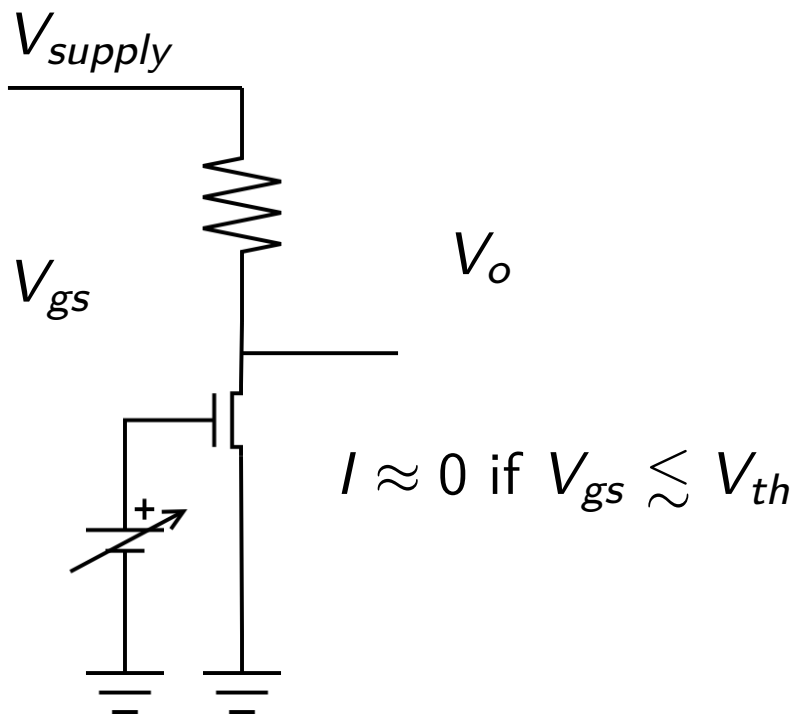
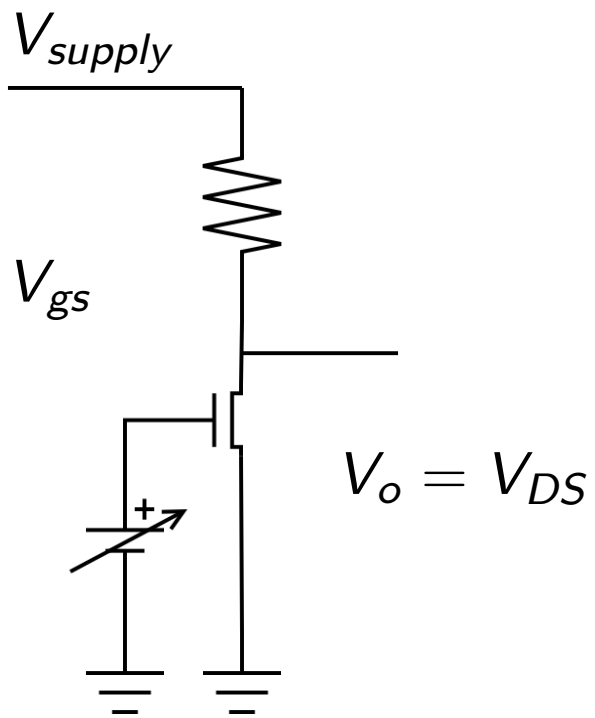


E (enhancement mode) MOSFET output zoomed in



E (enhancement mode) FET



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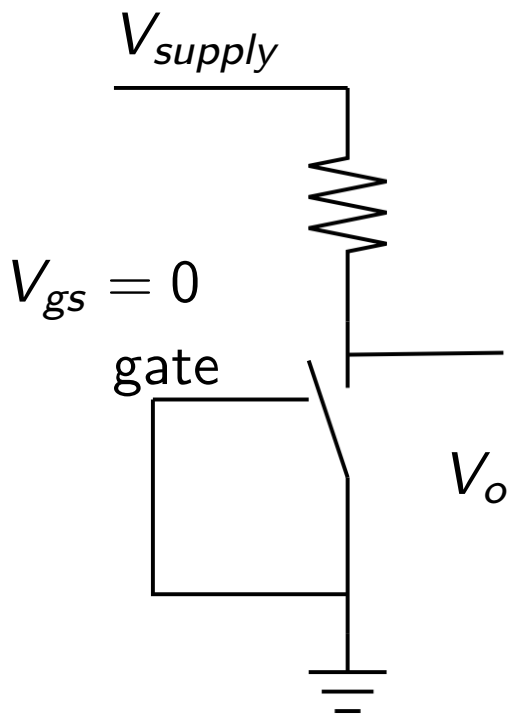

$V_o \approx V_{supply}$ if $V_{gs} < V_{th}$

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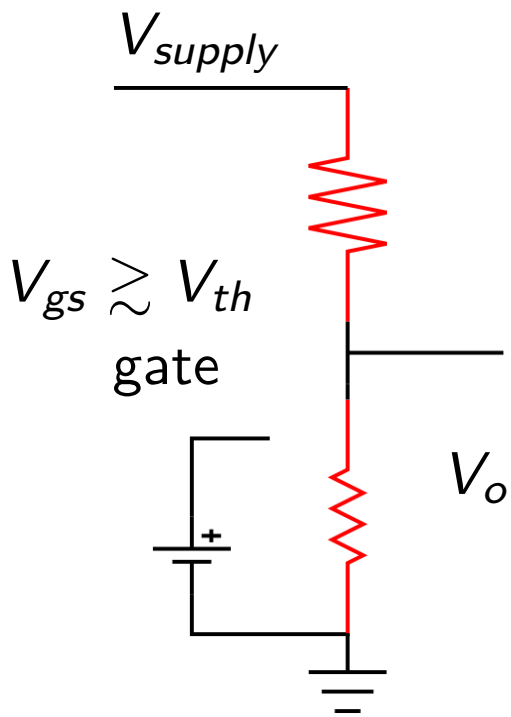

$V_o = V_{DS} < V_{supply}$ if $V_{gs} \gtrsim V_{th}$

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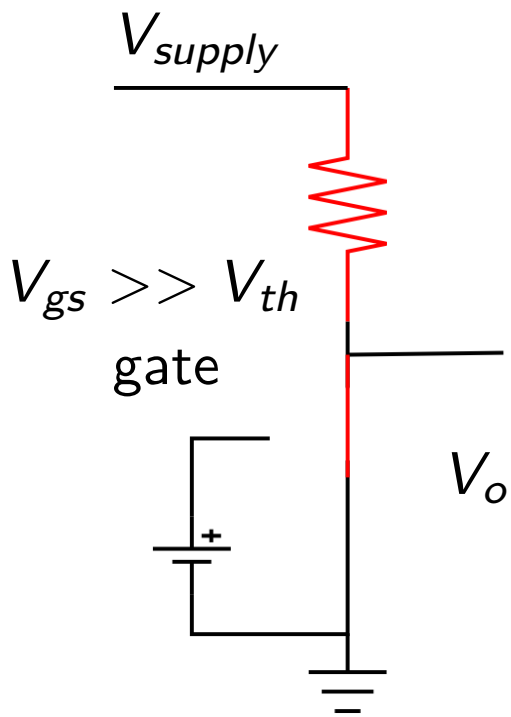

$V_o = V_{DS} \rightarrow 0$ if $V_{gs} >> V_{th}$

E (enhancement mode) FET

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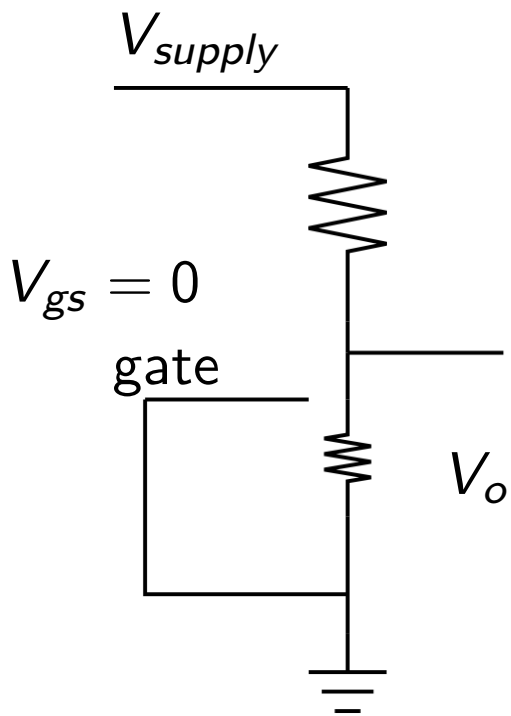
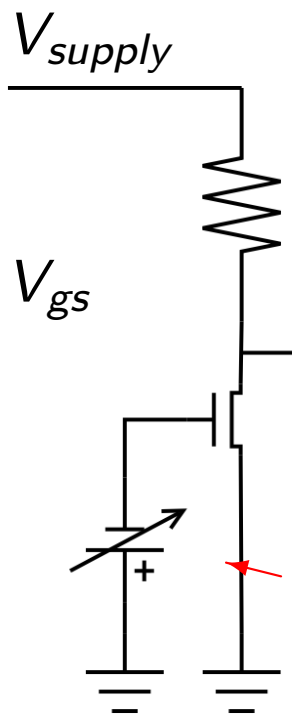
- All FETs work in *enhancement* mode; some also work in *depletion* mode.



$V_o = V_{DS} > 0$ if $V_{gs} = 0$

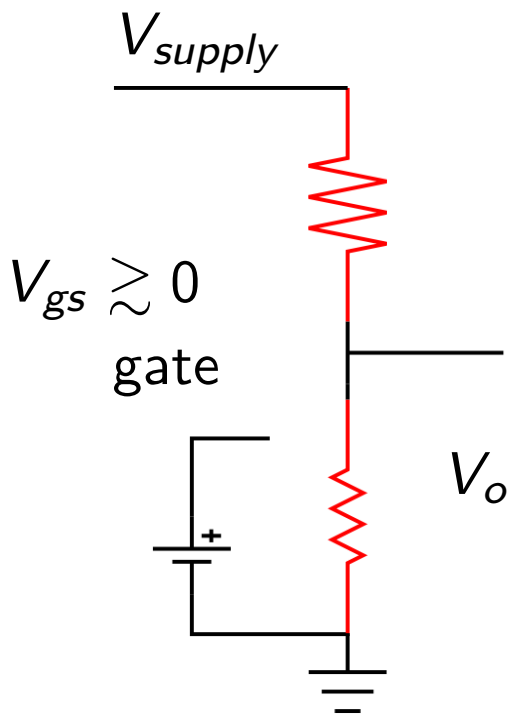
D (depletion mode) FET



$I \approx 0$ if $V_{gs} \lesssim V_{gs_{off}} < 0$

V_{gs} has to be negative to turn off.

D (depletion mode) FET



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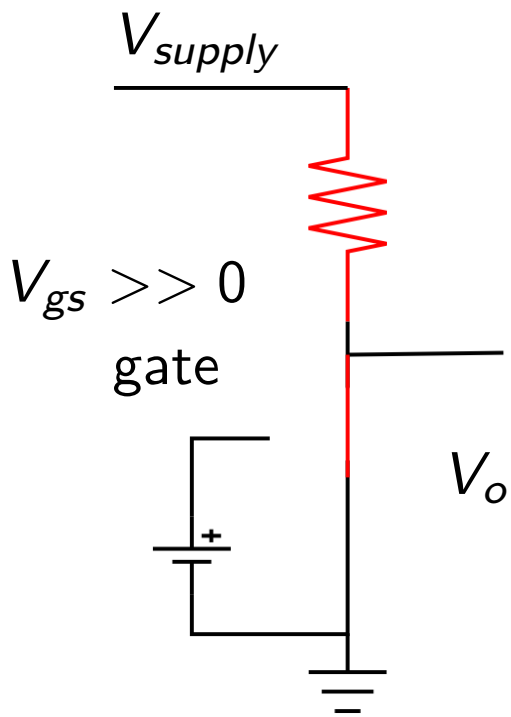

$V_o = V_{DS} \rightarrow 0$ if $V_{gs} >> 0$

D (depletion mode) FET

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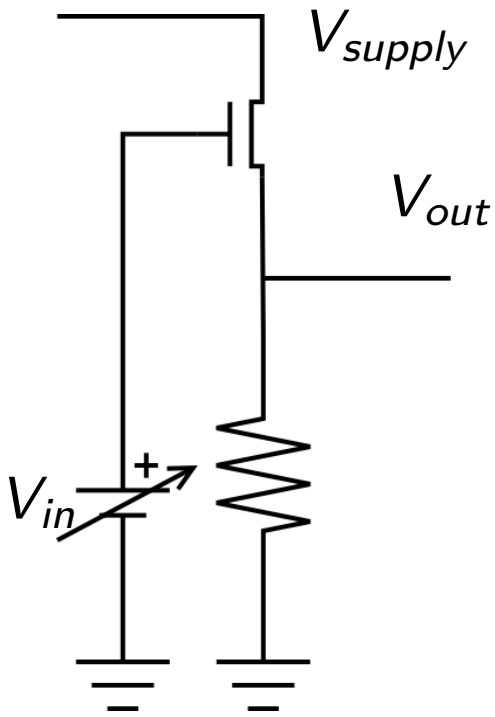

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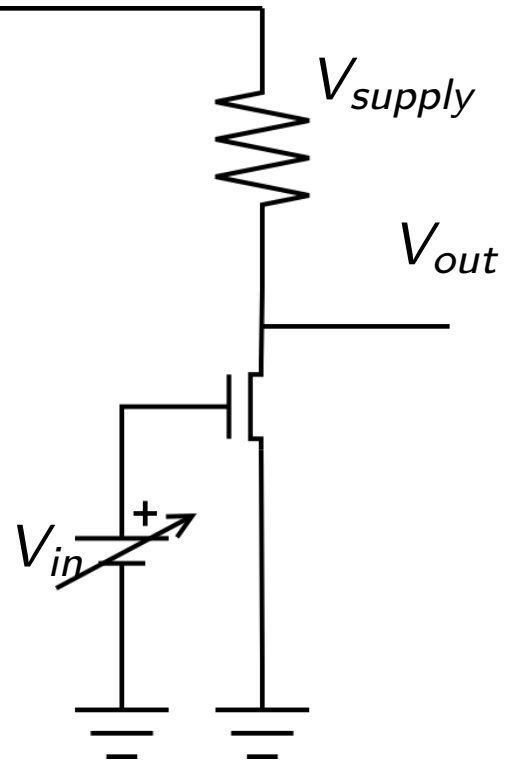

Bipolar Junction Transistors

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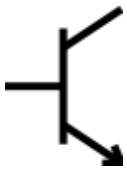
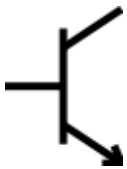
The current from the collector to the emitter is controlled by the *current* into the base.

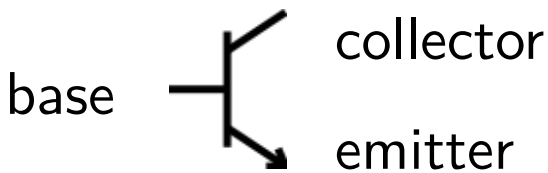


collector



collector

emitter


base
collector
emitter

BJT operation

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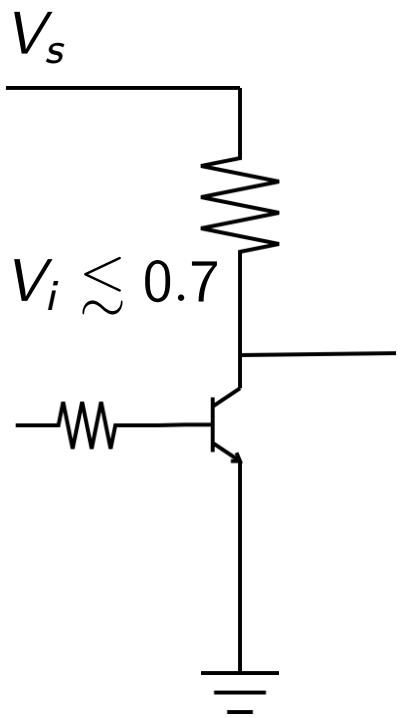
- *You should always have a base resistor with a BJT!*



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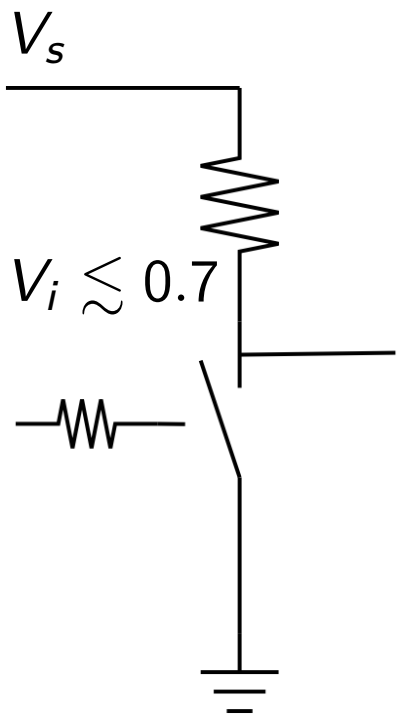

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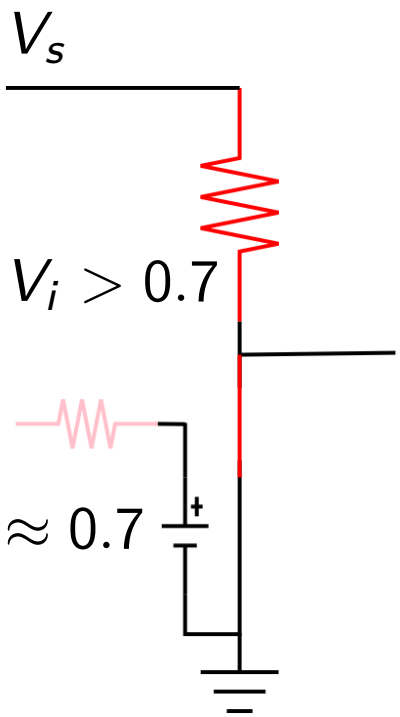

$$V_o = V_s - I_c R \text{ if } V_i > 0.7$$

$$I_c \propto I_b \text{ if } V_i > 0.7$$

Like the previous devices, either position in a voltage divider can be used.

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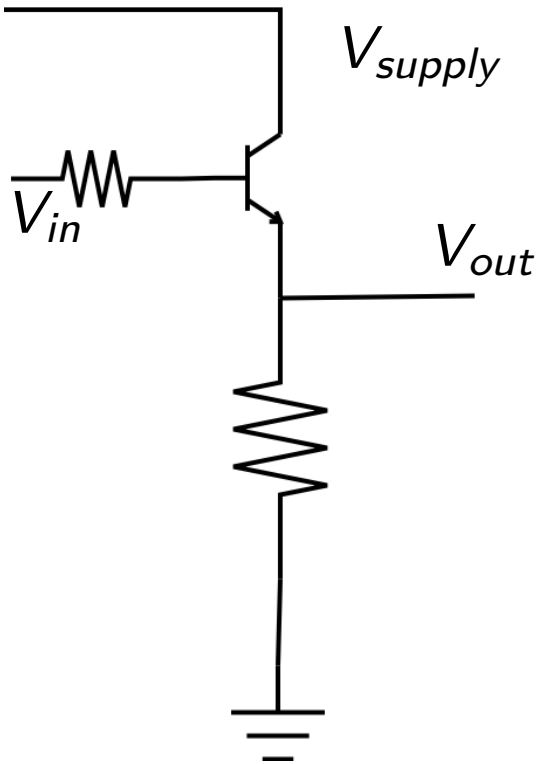

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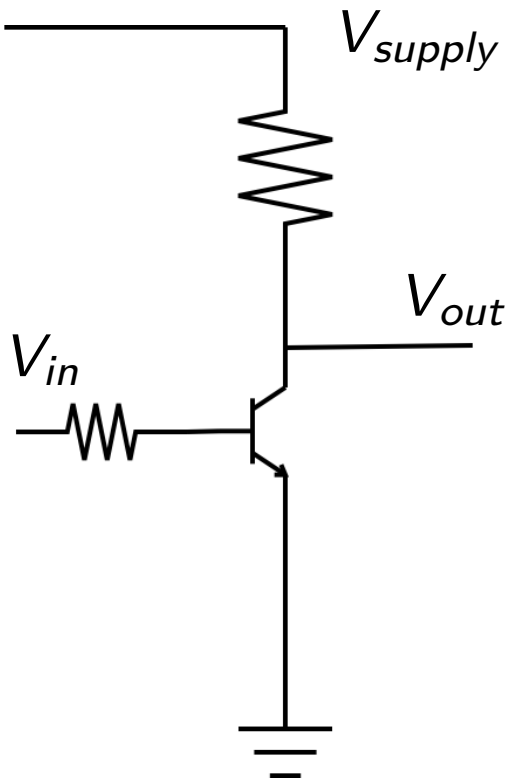

TRIAC

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A TRIAC is a three terminal *ac voltage* device.

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- main terminal 1

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- main terminal 2

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- main terminal 2
- gate

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A triac will begin to conduct when it receives a voltage pulse on the *gate*.

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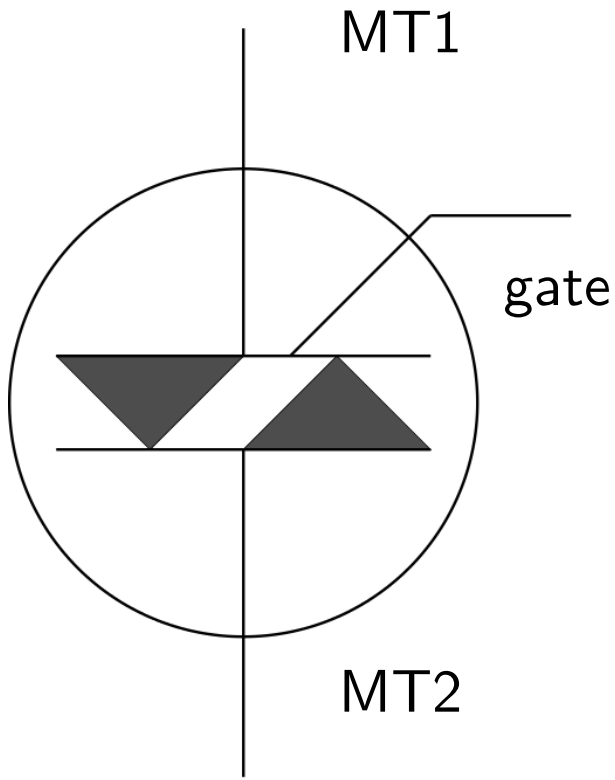
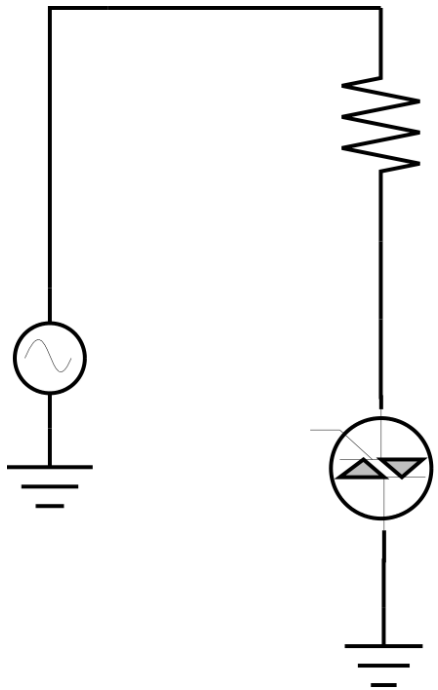
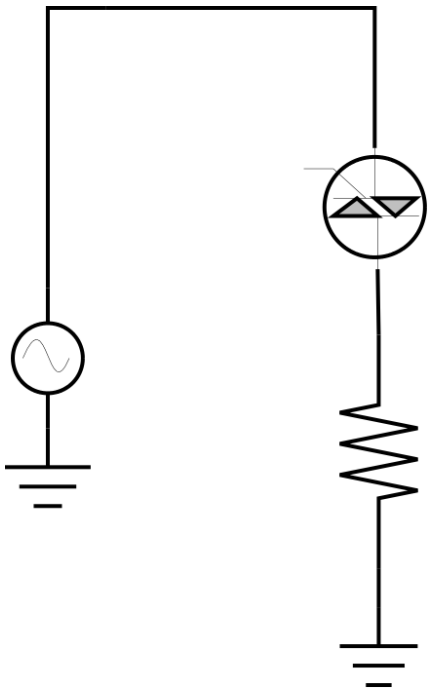
- main terminal 1
- main terminal 2
- gate

A triac will begin to conduct when it receives a voltage pulse on the *gate*. It will continue to conduct until the *current* is *zero*.


MT1
gate
MT2





It can operate in two modes.

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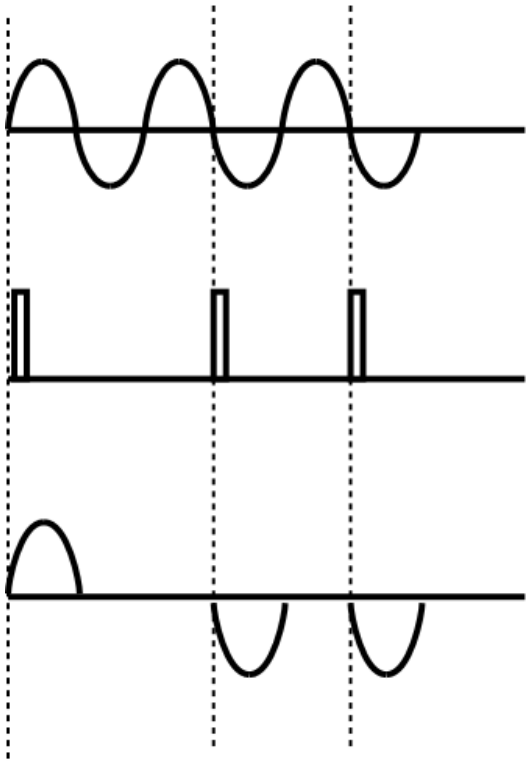
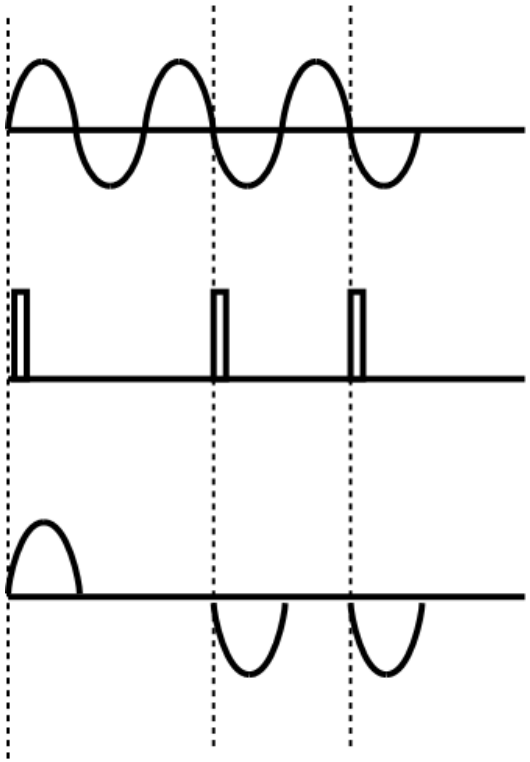
- burst

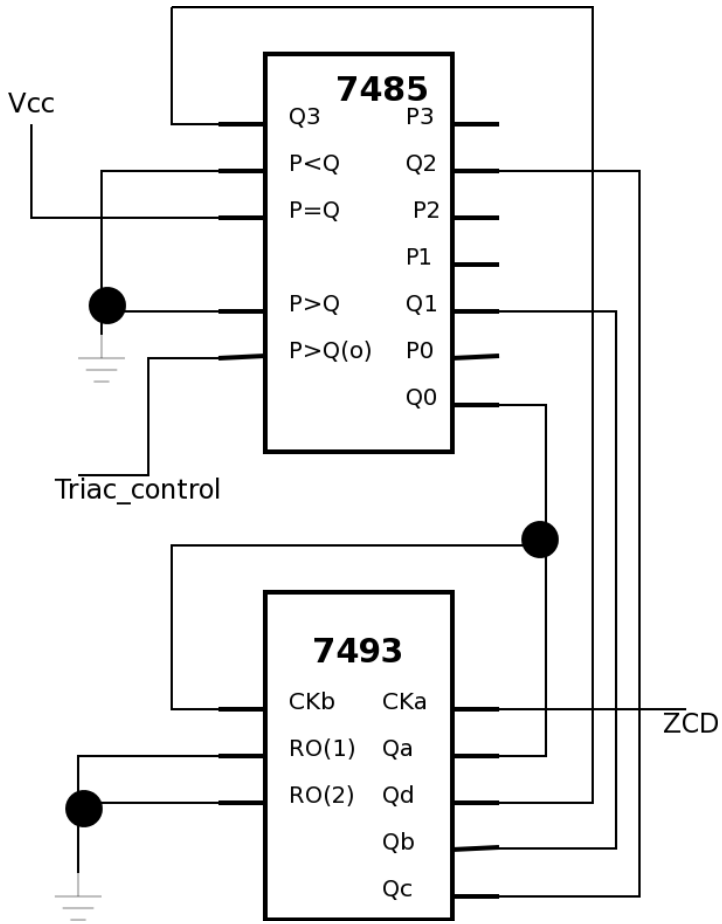
It can operate in two modes.

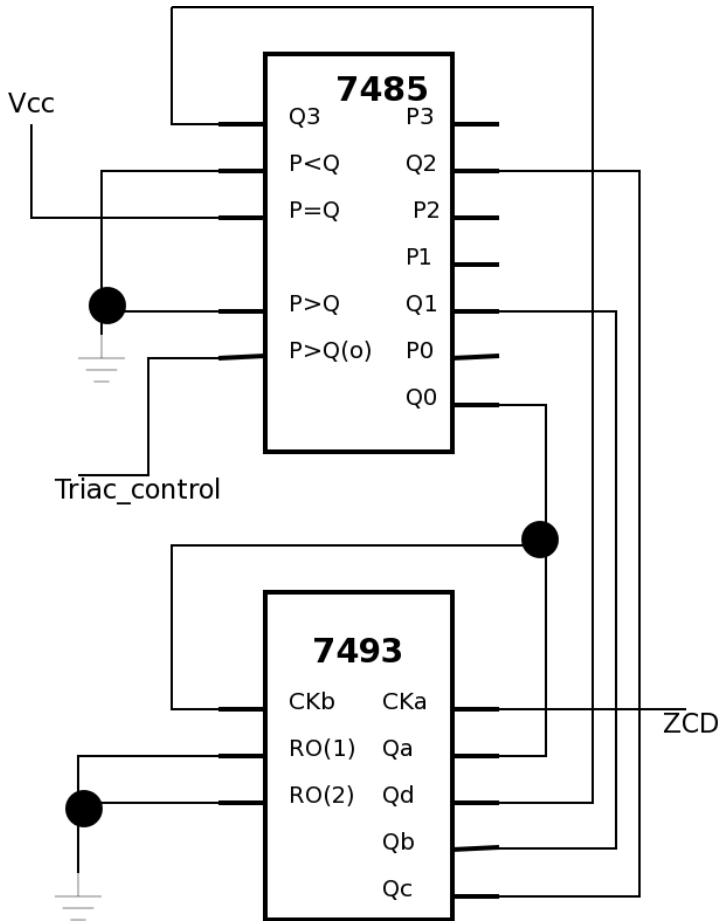
- burst
- delayed trigger



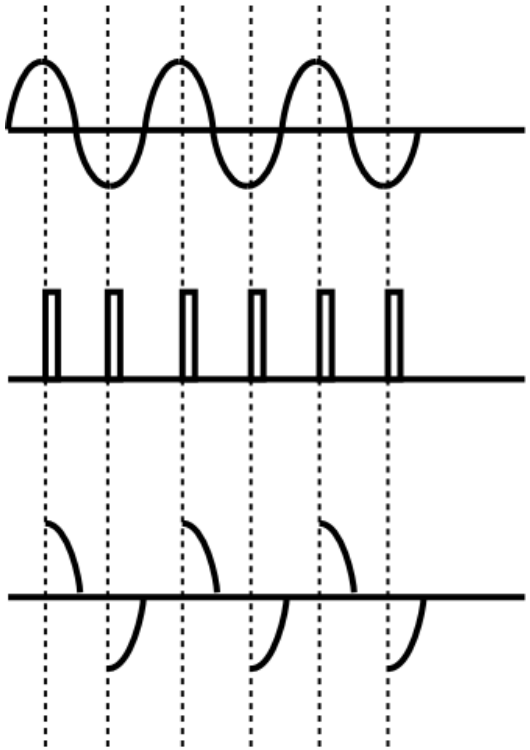


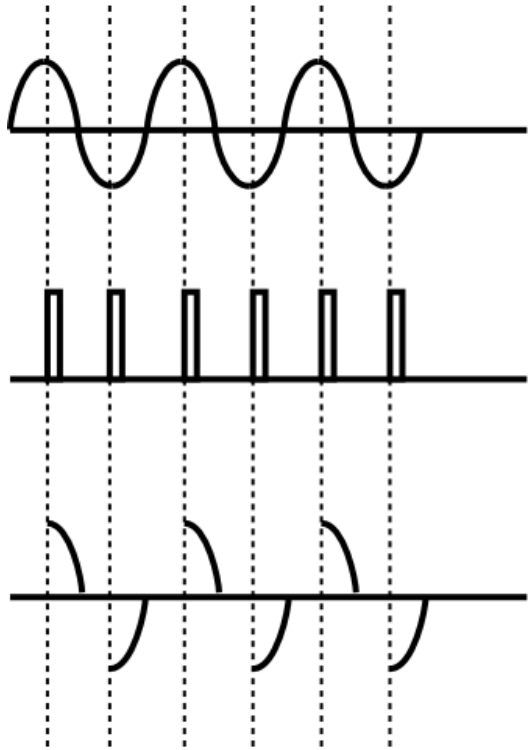
In *burst* mode, trigger pulses are only given at the beginning of half-cycles.


7485
Q3
P3
P<Q
Q2
P=Q
P2
P1
P>Q
Q1
P>Q(o)
P0
Q0
Vcc
Triac_control
7493
CKb
CKa
RO(1)
Qa
RO(2)
Qd
Qb
Qc
ZCD

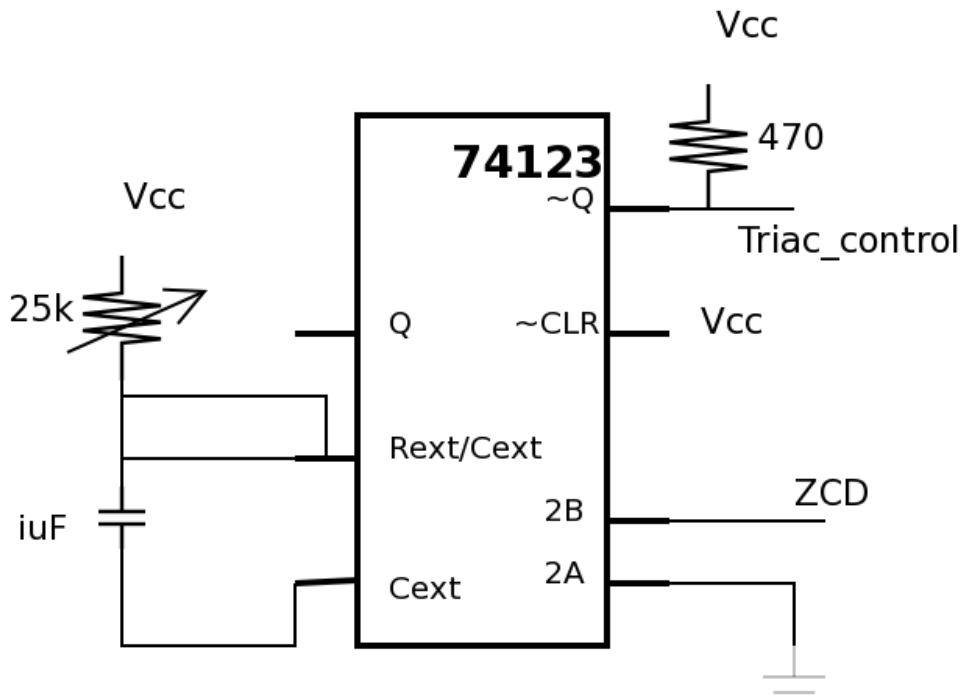


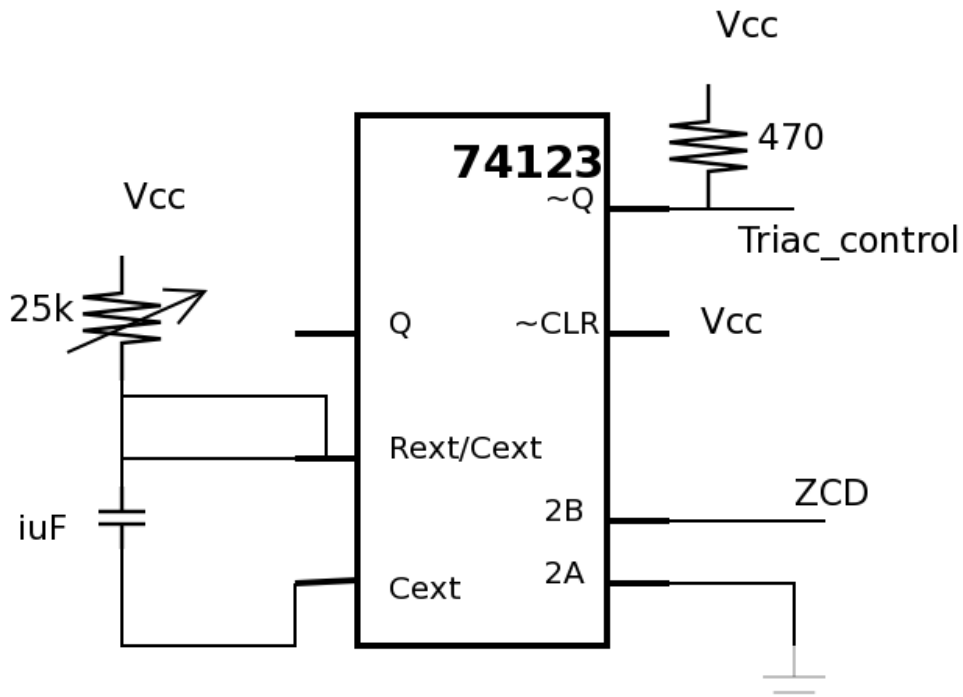
This is a typical circuit to control a triac in burst mode.





In *delayed trigger* mode, trigger pulses are delayed after the beginning of half-cycles to produce power for only a part of each half cycle.


Vcc
470
74123
~Q
Triac_control
Vcc
25k
Q
~CLR
Vcc
Rext/Cext
ZCD
iuF
2B
2A
Cext



This is a typical circuit to control a triac in delayed trigger mode.

Using TTL gates for control

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- "Extra" current from TTL

Using TTL gates for control

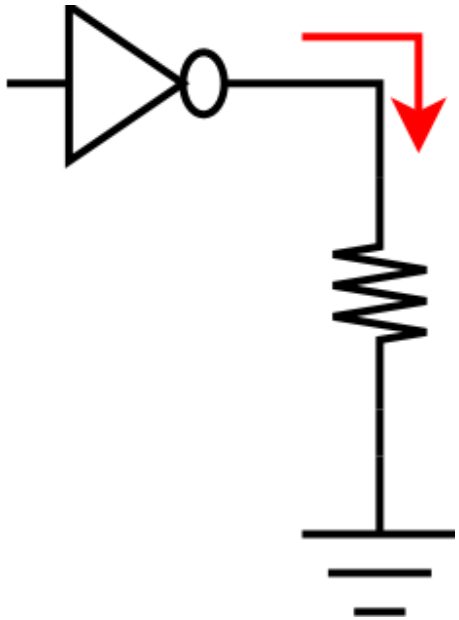
- "Extra" current from TTL
- sink instead of source

Using TTL gates for control

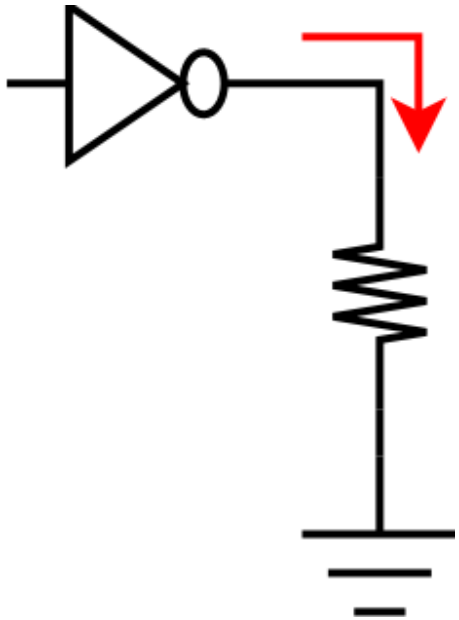
- "Extra" current from TTL
- sink instead of source
- 0.4mA vs. 8 mA (LS)

Current sourcing

Current sourcing



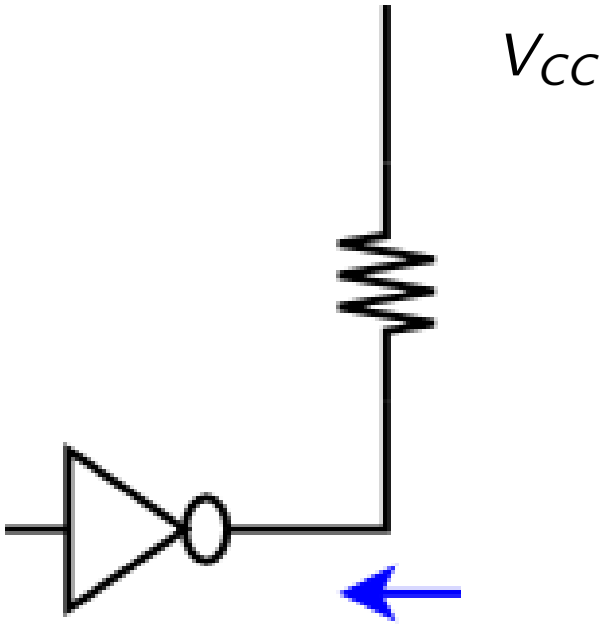
Current sourcing



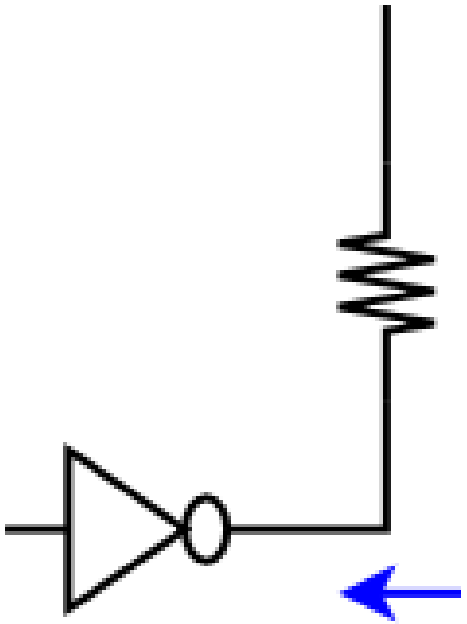
$I_{OH} \leq 0.4\text{mA}$

Current sinking

Current sinking



Current sinking



Using a TTL gate to sink instead of source allows 20x the current!