

# Introduction to Transistors

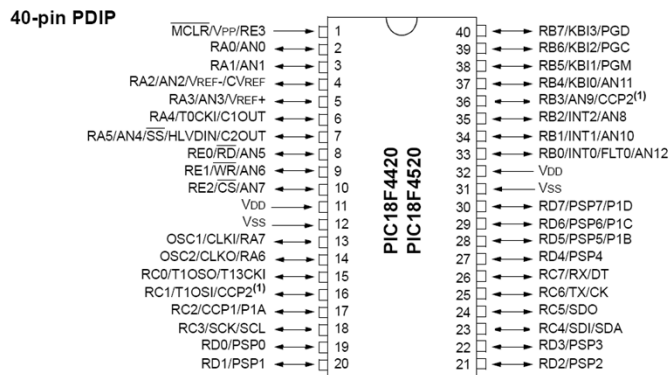
Prior to Day 2



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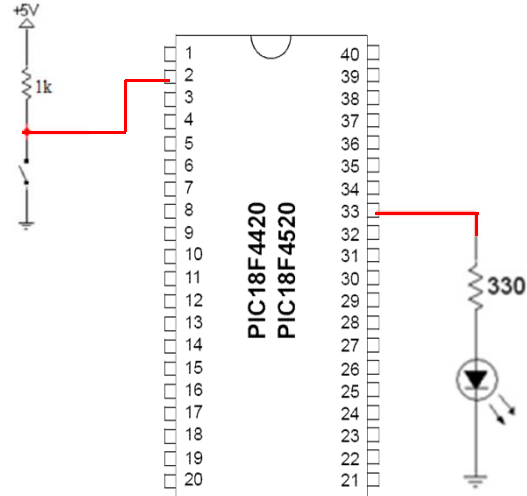
## Output power

- Typ 25 mA total source current (Max 45 mA)



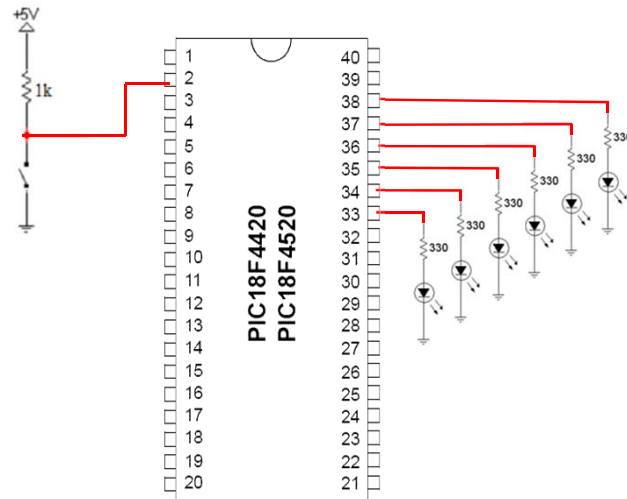
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## Driving an LED



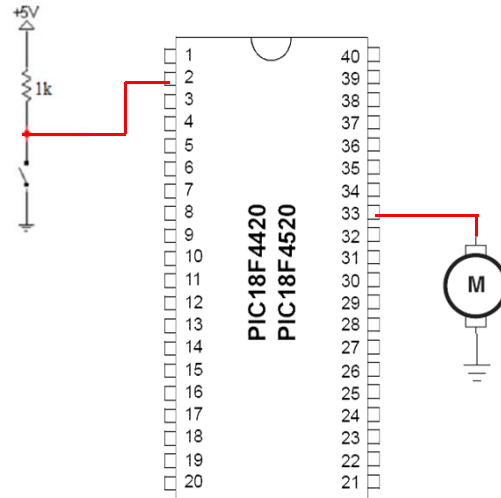
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## Driving many LEDs



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## Driving a motor

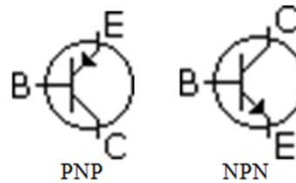
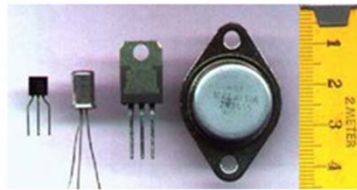


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## Need a buffer, need a switch to flip

### Transistor:

While not a mechanical switch, a transistor can be thought of as an electrically controlled switch.



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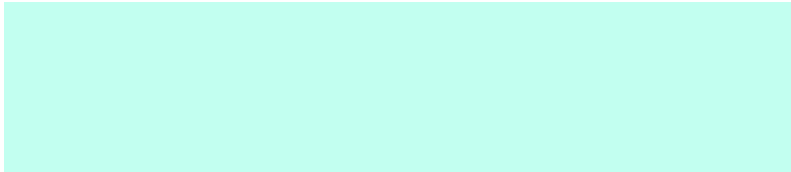
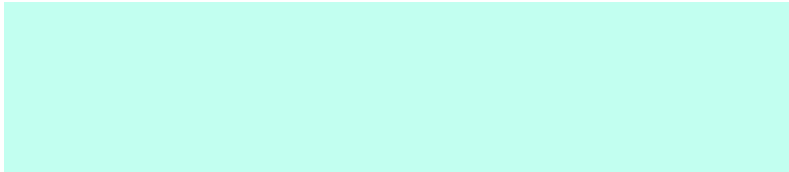
## History

- First transistor invented at Bell Labs in 1947
- Used to amplify electrical currents (not just on or off)
- Before it was developed, electron tubes (also called vacuum tubes) were the norm
- Just how many transistors are there in the world?
  - Biologist Edmund Wilson has estimated that there are about *100 quadrillion* ants on Earth.
  - In a single year there are about *100 transistors* produced for every ant on Earth, and production is continuing to increase.



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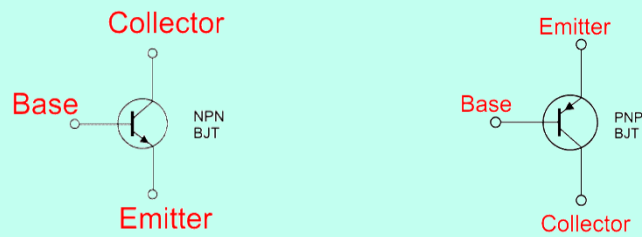
## Transistor types

- Bipolar Junction Transistors - BJT  

- Metal Oxide Semiconductor Field Effect Transistors – MOSFET  

- Other types of transistors
  - Darlingtons (special type of BJT), H-Bridges, Relays



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## BJT's as switches



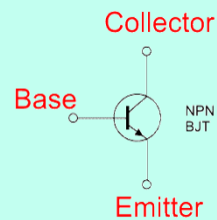
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## MOSFETs as switches



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## Sizing BJT Resistors



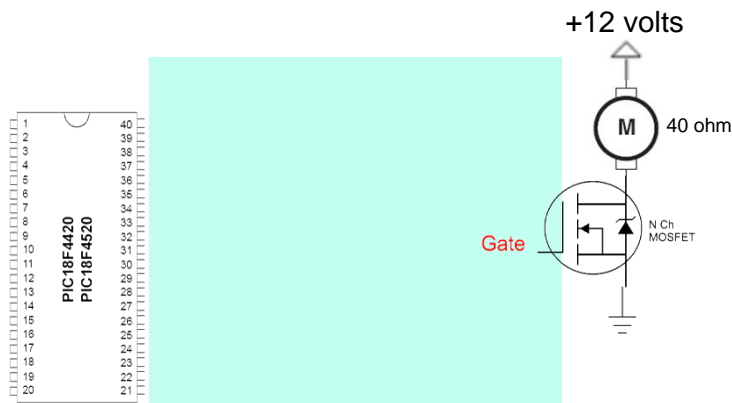
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## Your turn - BJT



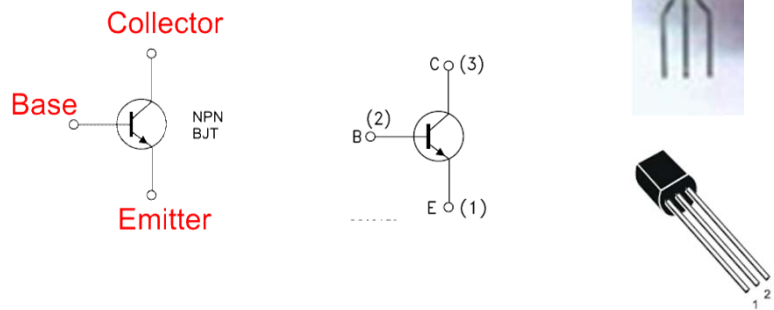
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# Your turn - MOSFET



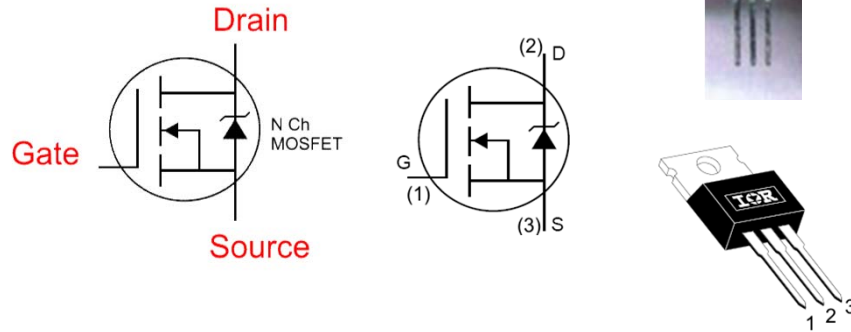
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# Real Devices - BJT



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# Real Devices - MOSFET



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# Datasheet - NPN



2N3904

SMALL SIGNAL NPN TRANSISTOR

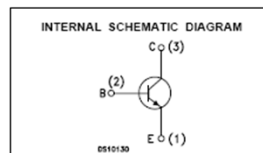
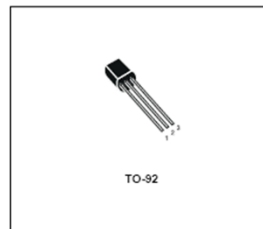
PRELIMINARY DATA

Type	Marking
2N3904	2N3904

- SILICON EPITAXIAL PLANAR NPN TRANSISTOR
- TO-92 PACKAGE SUITABLE FOR THROUGH-HOLE PCB ASSEMBLY
- THE PNP COMPLEMENTARY TYPE IS 2N3906

**APPLICATIONS**

- WELL SUITABLE FOR TV AND HOME APPLIANCE EQUIPMENT
- SMALL LOAD SWITCH TRANSISTOR WITH HIGH GAIN AND LOW SATURATION VOLTAGE



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## Datasheets - MOSFET

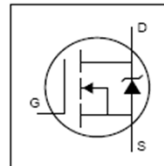
International  
**IR** Rectifier

PD - 9.1307B

**IRLZ34N**

HEXFET<sup>®</sup> Power MOSFET

- Logic-Level Gate Drive
- Advanced Process Technology
- Dynamic  $dv/dt$  Rating
- 175°C Operating Temperature
- Fast Switching
- Fully Avalanche Rated



$$V_{DS} = 55V$$

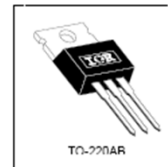
$$R_{DS(on)} = 0.035\Omega$$

$$I_D = 30A$$

### Description

Fifth Generation HEXFETs from International Rectifier utilize advanced processing techniques to achieve the lowest possible on-resistance per silicon area. This benefit, combined with the fast switching speed and ruggedized device design that HEXFET Power MOSFETs are well known for, provides the designer with an extremely efficient device for use in a wide variety of applications.

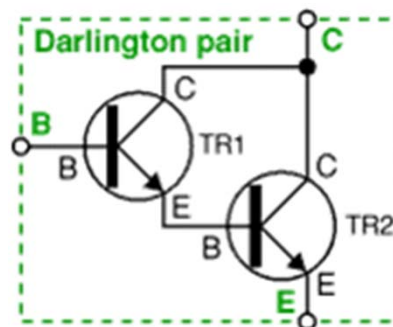
The TO-220 package is universally preferred for all commercial-industrial applications at power dissipation levels to approximately 50 watts. The low thermal resistance and low package cost of the TO-220 contribute to its wide acceptance throughout the industry.



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## Darlington

- Two NPN BJT transistors arranged to work well as a switch



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# Darlingtontons in an IC

- Built in resistor to control current
- Built in Snubber Diode (next lecture)
- 7 in a package!



ULN2001A-ULN2002A  
ULN2003A-ULN2004A

SEVEN DARLINGTON ARRAYS

- SEVEN DARLINGTONS PER PACKAGE
- OUTPUT CURRENT: 500mA PER DRIVER (500mA PEAK)
- OUTPUT VOLTAGE 50V
- INTEGRATED SUPPRESSION DIODES FOR INDUCTIVE LOADS
- OUTPUTS CAN BE PARALLELED FOR HIGHER CURRENT
- TTL/CMOS/PMOS/DTL COMPATIBLE INPUTS
- INPUTS PINNED OPPOSITE OUTPUTS TO SIMPLIFY LAYOUT



DESCRIPTION

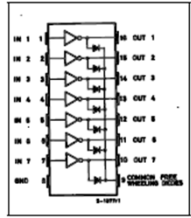
The ULN2001A, ULN2002A, ULN2003 and ULN2004A are high voltage, high current darlington arrays each containing seven open collector darlington pairs with common emitters. Each channel rated at 500mA and can withstand peak currents of 600mA. Suppression diodes are included for inductive load driving and the inputs are pinned opposite the outputs to simplify board layout. The four versions interface to all common logic families:

ULN2001A	General Purpose, DTL, TTL, PMOS, CMOS
ULN2002A	5V TTL, PMOS
ULN2003A	5V TTL, CMOS
ULN2004A	5-Volt CMOS, PMOS

These versatile devices are useful for driving a wide range of loads including solenoids, relays, DC motors, LED displays, filament lamps, thermal print-heads and high power buffers.

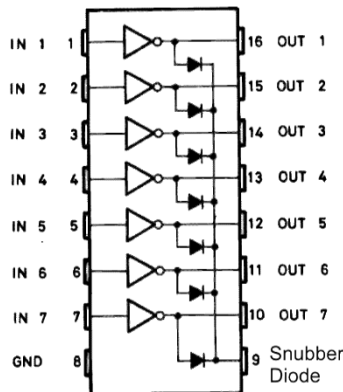
The ULN2001A/2002A/2003A and 2004A are supplied in 16 pin plastic DIP packages with a copper leadframe to reduce thermal resistance. They are available also in small outline package (SO-16) as ULN2001D/2002D/2003D/2004D.

PIN CONNECTION



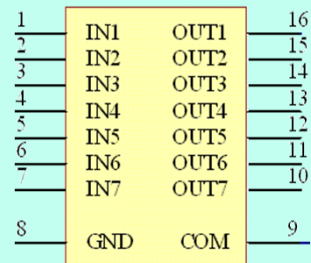
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# ULN2003



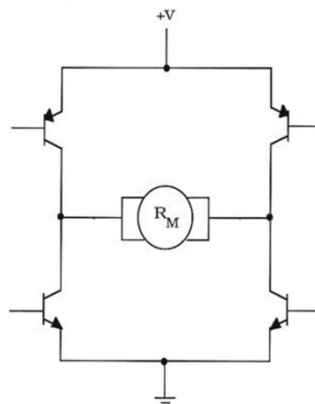
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## ULN2003 Circuit



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## H-Bridge



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## Relays

- Higher current switching

