第十三讲
元器件
Lecture 13
Components

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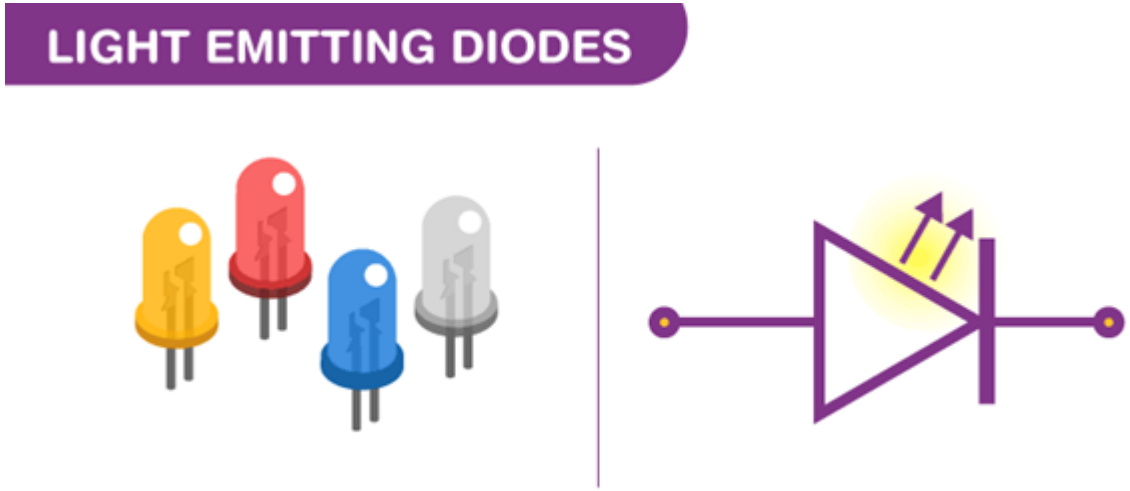
发光二极管
Light-emitting Diode

- 发光二极管（LED）是一种能将电能转化为光能的半导体元件，其电气符号如下图所示，即在普通二极管表示的基础上加发射状的箭头。LED的正极(或阳极)引脚通常用A表示，而负极(或阴极)引脚通常用K表示。LED与普通二极管一样是由一个PN结组成，也具有单向导电性，只是LED可以发光。LED施加正向电压时，电子和空穴就会移动并在结合部再次结合，正是在结合的过程中产生大量的能量，而这些能量以光的形式释放出来。LED与先将电能转换为热能，再转换为光能的热光源相比，因为其能够直接将电能转换为光能，因此具有很高的效率。



发光二极管
Light-emitting Diode

- 根据LED的封装和颜色等，LED可被分成多种类型。市面上有直插型LED、贴片型LED。根据颜色有单色、双色和RGB全彩型LED等。不同颜色的LED的正向电压如下表所示：

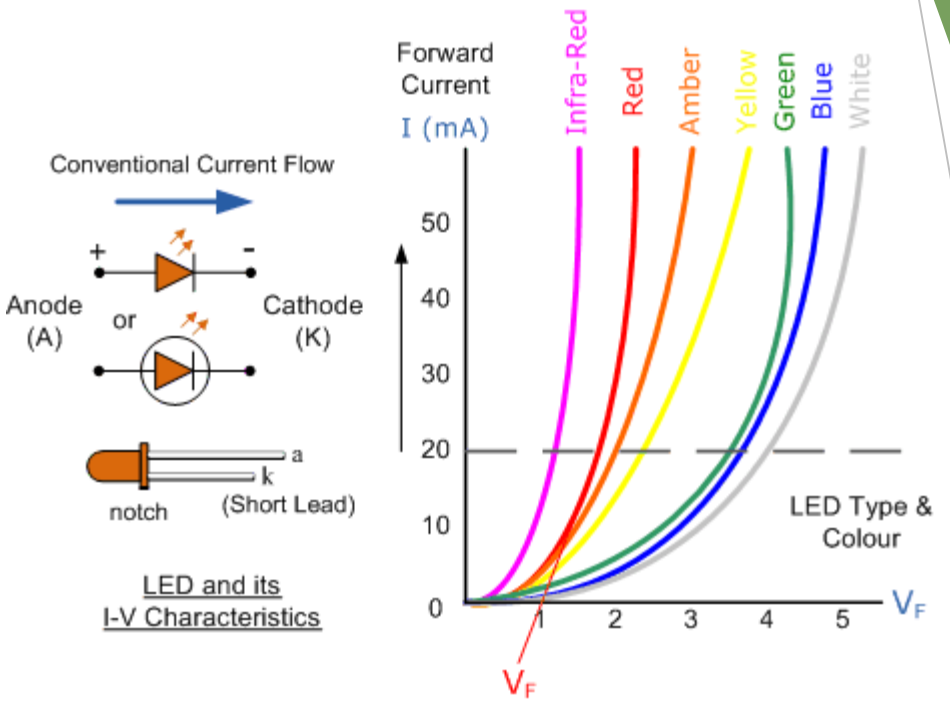
According to the packaging and emitting color of light, LEDs on the market can be divided into various types. There are in-line LEDs, SMD LEDs, and monochrome, bicolor and RGB full-color LEDs according to the color. The forward voltages of different colored LEDs are shown in the following table:

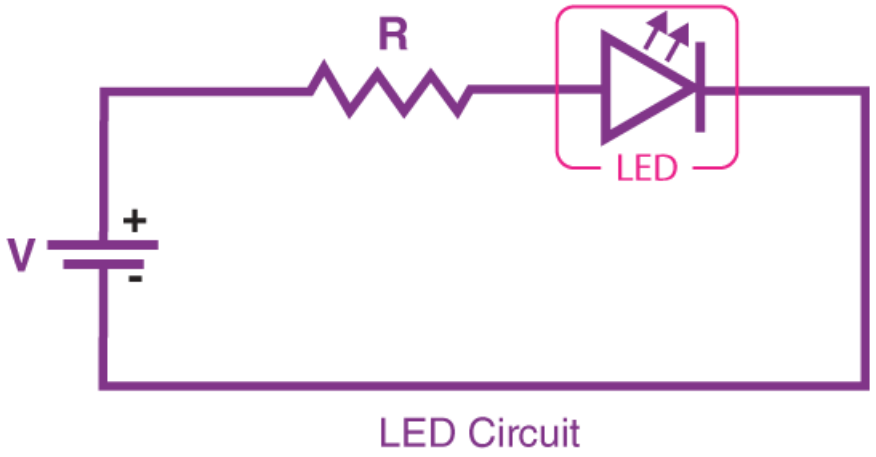
Typical LED Characteristics			
Semiconductor Material	Wavelength	Colour	V_F @ 20mA
GaAs	850-940nm	Infra-Red	1.2v
GaAsP	630-660nm	Red	1.8v
GaAsP	605-620nm	Amber	2.0v
GaAsP:N	585-595nm	Yellow	2.2v
AlGaP	550-570nm	Green	3.5v
SiC	430-505nm	Blue	3.6v
GaInN	450nm	White	4.0v

发光二极管
Light-emitting Diode

- 由于LED本质依然是二极管，因此遵循二极管的I-V特性曲线，即当正向电压高于导通电压时，正向电流急剧增大，有可能会烧坏二极管。因此，在日常使用中，需要串联电阻保护，如图所示：

Since the LED is essentially a diode, which still merits the I-V characteristic curve of the diode. When the forward voltage is higher than the threshold voltage, the dramatically increased current might cause the diode damaged. In practice, resistance is connect in series to prevent the diodes from overheating, as shown in the figure :



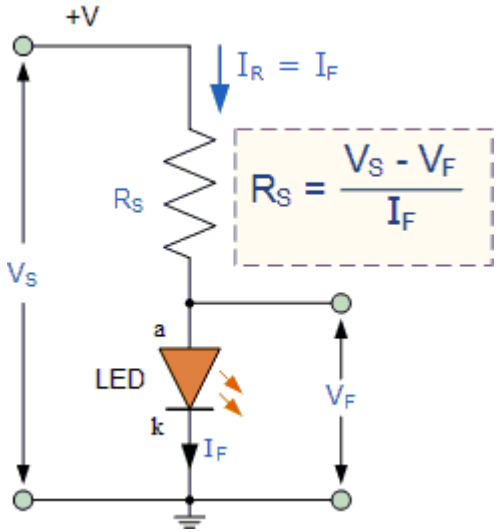


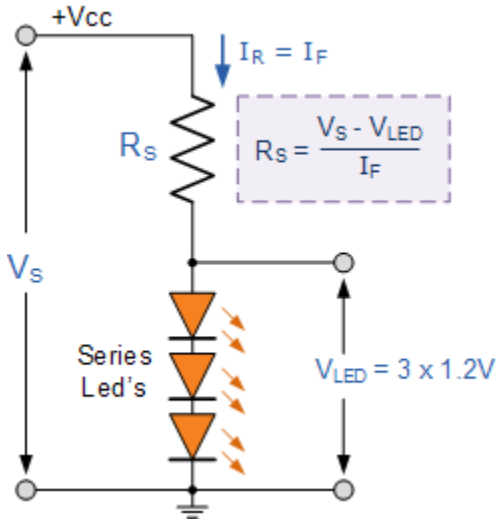
LED Circuit

发光二极管
Light-emitting Diode

- 因此，我们需要能够根据欧姆定律，计算出串联电阻的阻值R_S。基本思路是结合电源电压V_S和LED的预期正向压降V_F，在通过LED所需的正向电流I_F的水平下，计算限流电阻：

  Therefore, we should be able ot find out the resistance of the series resistor value R_S by using Ohm´s Law. The basic idea is by take account of the supply voltage V_S across the combination and the expected forward voltage drop of the LED, VF at the required forward current level I_F of the LED, the current limiting resistor is calculated as:





发光二极管
Light-emitting Diode

- 例：将前向压降为2V的单只琥珀色LED连接到5V的稳定直流电源。计算（1）将正向电流限制在10mA以下所需的串联电阻值；（2）如果使用100Ω串联电阻值，计算流过二极管的电流。

An amber colored LED with a forward volt drop of 2 volts is to be connected to a 5.0v stabilized DC power supply. (1) Calculate the value of the series resistor required to limit the forward current to less than 10mA. (2) Calculate the current flowing through the diode if a 100Ω series resistor is used.

1). series resistor required at 10mA.

$$R_S = \frac{V_S - V_F}{I_F} = \frac{5v - 2v}{10mA} = \frac{3}{10 \times 10^{-3}} = 300\Omega$$

2). with a 100Ω series resistor.

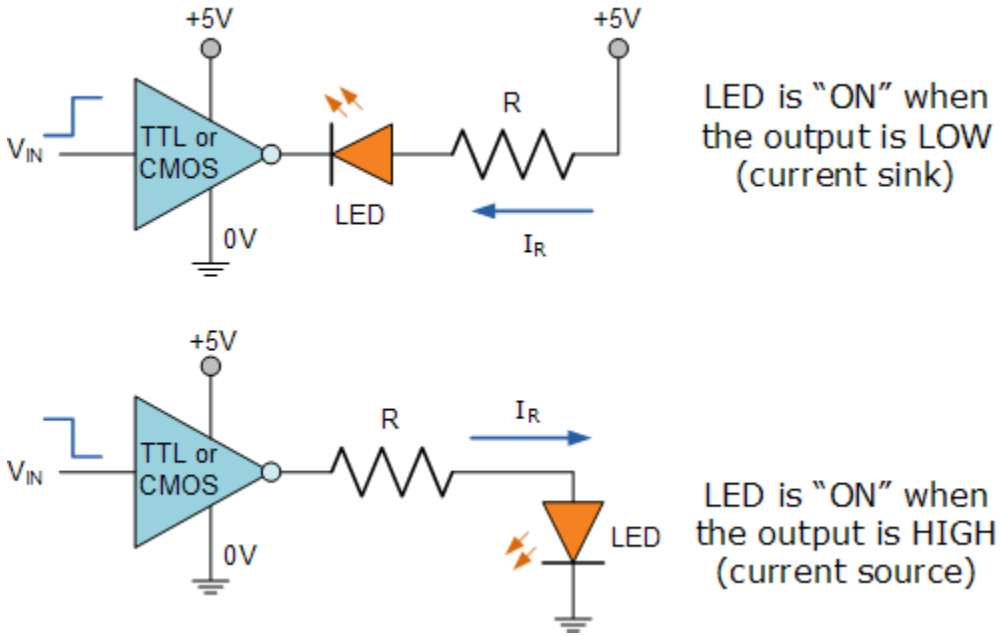
$$R_S = \frac{V_S - V_F}{I_F}$$

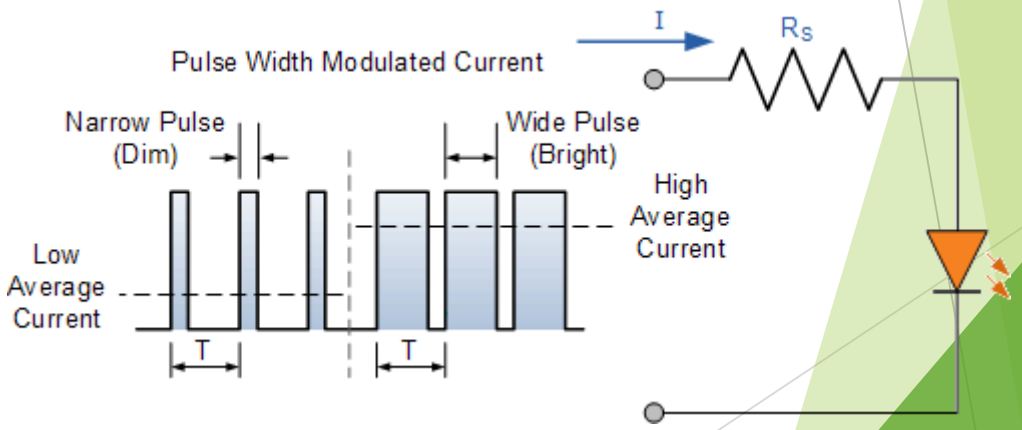
$$\therefore I_F = \frac{V_S - V_F}{R_S} = \frac{5 - 2}{100} = 30mA$$

发光二极管
Light-emitting Diode

- 在比较复杂的场景中，可能会用专门的驱动电路与脉冲宽度调制来控制LED:

  In complex scenarios, some dedicated driver circuits and PWM might be utilized to control the LED:





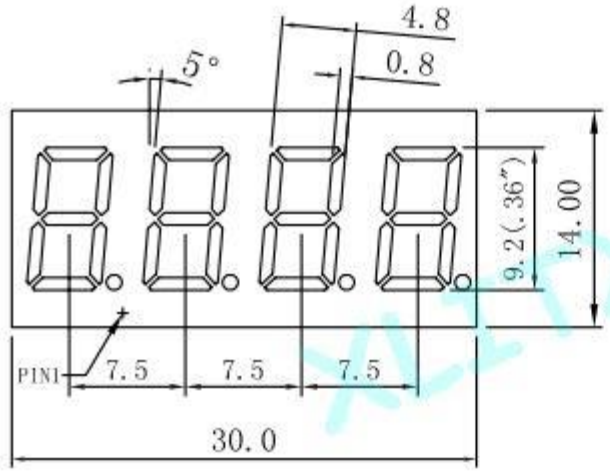
四位七段数码管
4 Digit 7 Segment Display

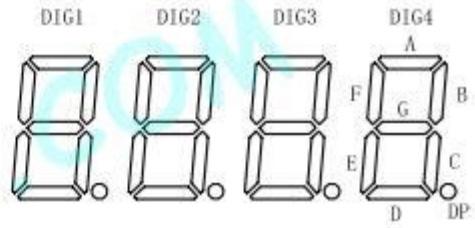
- 数码管是基于LED封装的显示器件通过对其不同的管脚输入相对的电流，使其发亮，从而显示出可用数字表示的参数。

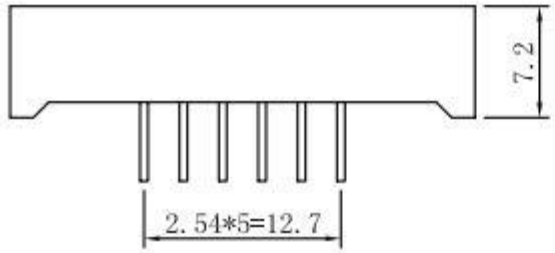
  A digital display is a device based on LED package that illuminates by current flow to its different pins, thereby displaying parameters that can be represented digitally.

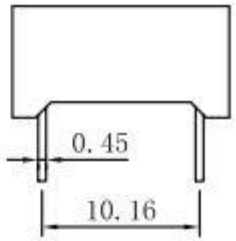
- 我们以四位七段数码管3461AS-1来讲解该元件的使用。该数码管发光颜色为红光，可显示4位数字（包含4个小数点），采用共阴极设计。

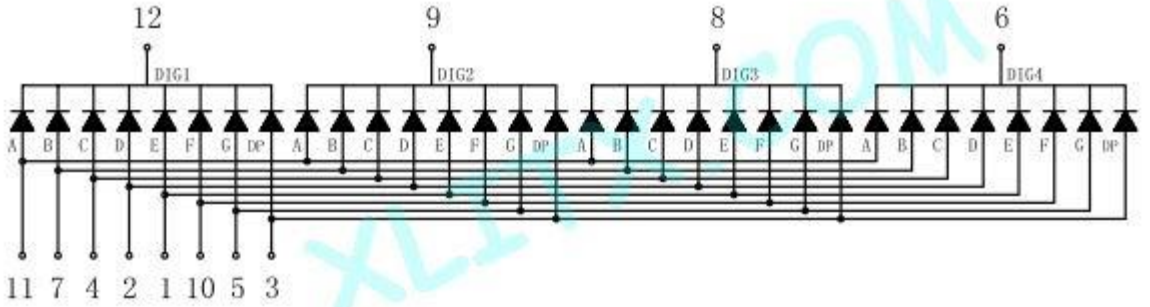
  We introduce the use of 4-digit 7-segment display by considering 3461AS-1. The emitting color of this component is red. It can display 4 digits (including 4 decimal points), and adopts a common cathode design.











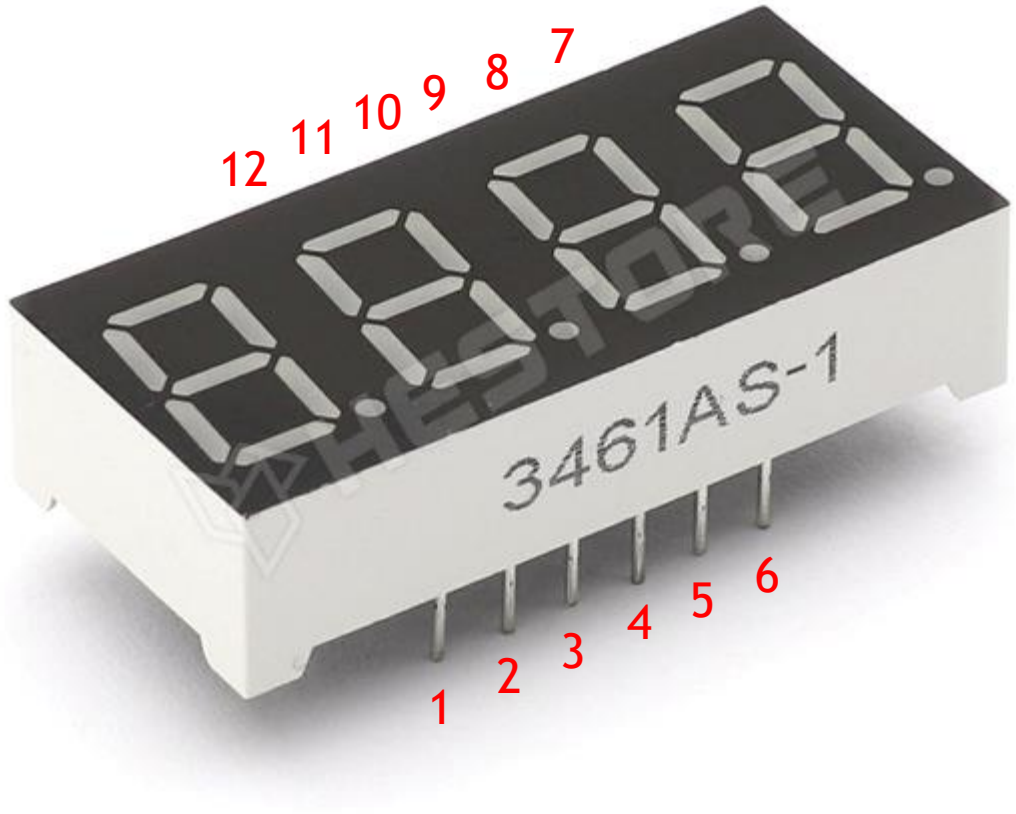
四位七段数码管
4 Digit 7 Segment Display

- 由于具有小数点，因此也有人称为3641系列为八段数码管。

  Due to the extra DP dot, the 3641 series are sometimes also referred as 8-segment display.

- 注意到在上页图中，左上角的小图中标识了第一个管脚的位置。则一般习惯成俗，按逆时针方向分别为管脚1，管脚2，直到管脚12。我们在右图中标出了管脚。

  Note in the figure of last slide, the position of pin 1 is denoted in the top-left sub-figure. In convention, along the direction of counter-clockwise, there are pins 1, 2, …, 12. We label all of them in the right figure.



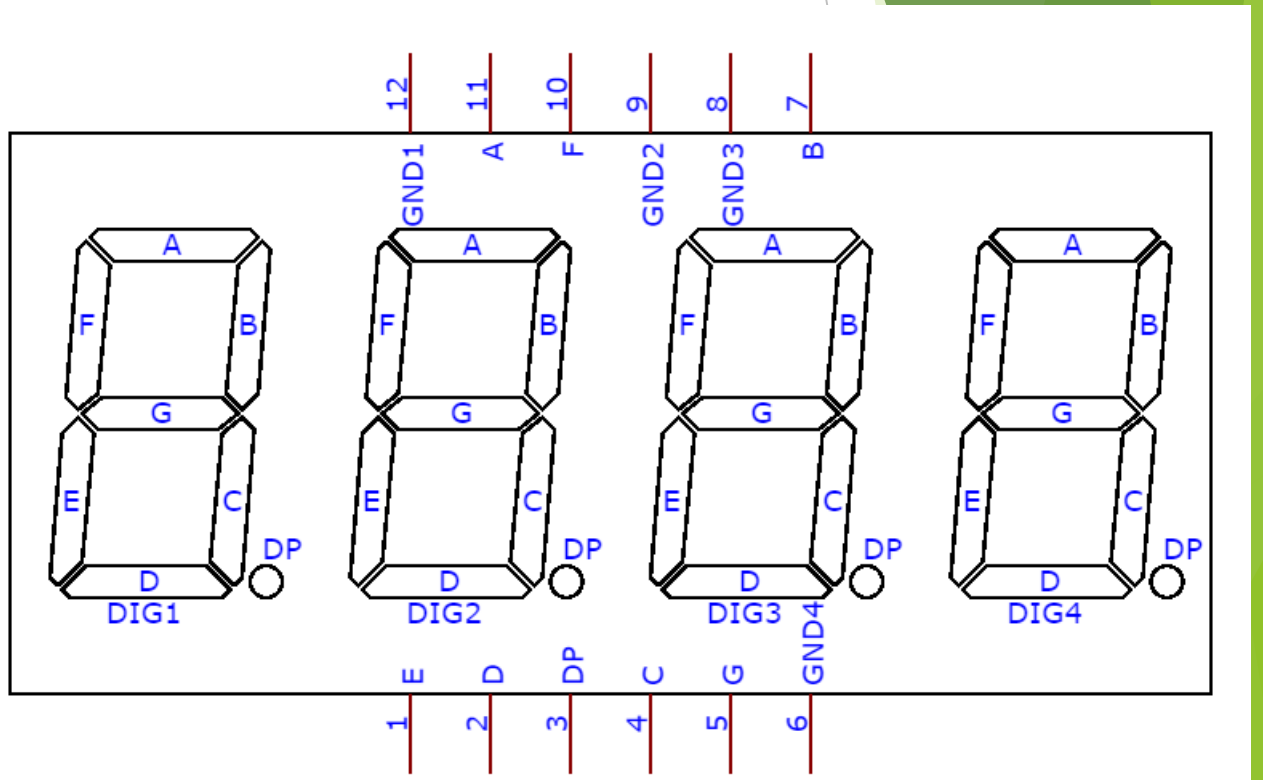
四位七段数码管
4 Digit 7 Segment Display

- 工作时，就是接通不同的管脚，点亮对应的LED组，首先实现单个字符控制，再利用人眼的视觉暂留原理，依次刷新，达到整体显示的目的 。

  During working, different pins are turned on to light up the corresponding LED group, to firstly control one character. Due to the vision persistence of human eyes, all the characters are refreshed in turn to achieve the effect of overall display.

- 在具体设计时，为了对应的方便，常将说明书中给的各段的字母标签，与各个管脚对应起来，方便连线与控制。

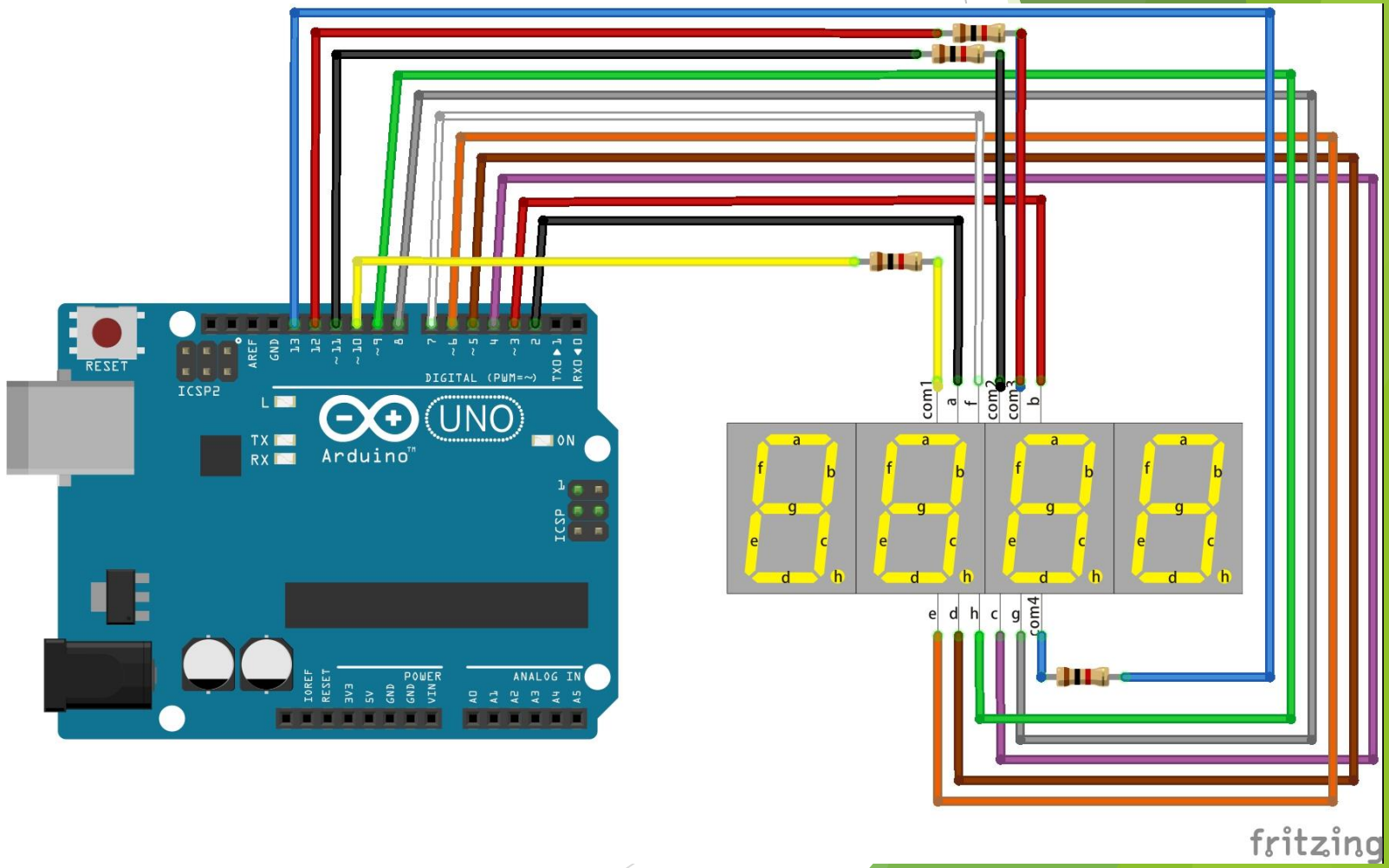
  During design, for convenience, it is a practice to put the letters which label the segments as indicated in the manual to the pin. In this may it is manifest for wiring and controlling.



四位七段数码管
4 Digit 7 Segment Display

- 典型的利用Arduino驱动四位数码管的接线图如右所示，为防止电流过大烧坏二极管，会在共阴极与板子的管脚之间串接一个适当的电阻，如1kΩ。然后可以根据Arduino的SevSeg库进行编程，控制数字的显示。

A typical wiring diagram for driving a four-digit digital display with Arduino is shown on the right. In order to prevent excessive current from damaging the diode, an appropriate resistor, such as 1k Ω, is connected in series between the common cathode and the pin of the board. Then utilize the SevSeg library from Arduino IDE to program the 7-segment display.



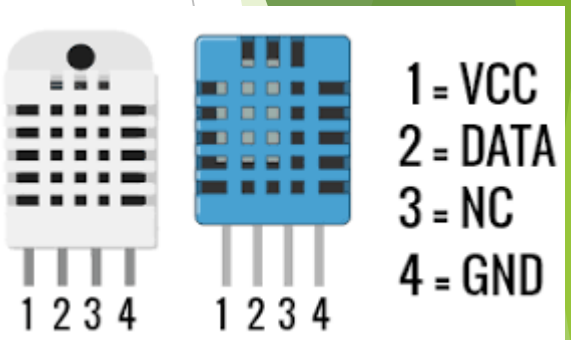
温湿度传感器
Temperature and Humidity Sensor

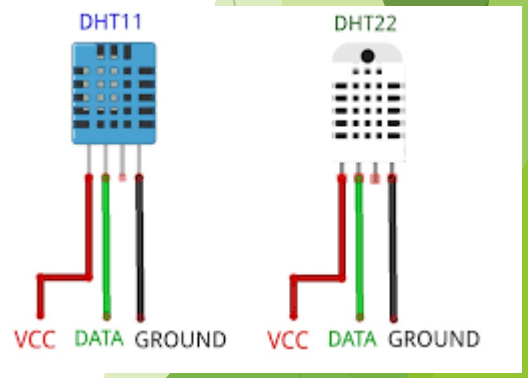
- 我们这里仅介绍低成本的DHT温度和湿度传感器，尽管它们非常基础且速度慢，但对一些爱好者来说已足够用。DHT传感器通常由两部分组成，基于电容的湿度传感器和基于热敏电阻的温度传感器。通常DHT模块里面还有一个非常基础的芯片，可以进行一些模数转换，并输出带有温度和湿度的数字信号，供微控制器进行读取。

  We just cover the low cost DHT temperature & humidity sensors here, which are very basic and slow, but are great for hobbyists. The DHT sensors are made of two parts, a capacitive humidity sensor and a thermistor. There is also a very basic chip inside that does some analog to digital conversion and spits out a digital signal with the temperature and humidity, to facilitate the reading by microcontrollers.

- 我们常用的DHT为DHT11与DHT22两个版本，它们看起来有点相似并且具有相同的引线，但具有不同的特性。

  The commonly used DHT sensors are DHT11 and DHT22, they look a bit similar and have the same pinout, but have different characteristics.





温湿度传感器
Temperature and Humidity Sensor

- DHT11与DHT22的规格如下表所示，可见DHT22有稍大的测量范围内且精确度更好。同时，两者都使用一个数字引脚，并且“缓慢”，即查询间隔不建议少于两秒。

  The specs of DHT11 and DHT22 are in the following table. As you can see, the DHT22 is a little more accurate and good over a slightly larger range. Both use a single digital pin and are 'sluggish' in that you can't query them more than once every second or two seconds.

DHT11	DHT22
Ultra low cost	Low cost
3 to 5V power and I/O	3 to 5V power and I/O
2.5mA max current use during conversion (while requesting data)	2.5mA max current use during conversion (while requesting data)
Good for 20-80% humidity readings with 5% accuracy	Good for 0-100% humidity readings with 2-5% accuracy
Good for 0-50° C temperature readings ±2° C accuracy	Good for -40 to 80° C temperature readings ±0.5° C accuracy
No more than 1 Hz sampling rate (once every second)	No more than 0.5 Hz sampling rate (once every 2 seconds)
Body size 15.5mm x 12mm x 5.5mm	Body size 15.1mm x 25mm x 7.7mm
4 pins with 0.1" spacing	4 pins with 0.1" spacing

温湿度传感器
Temperature and Humidity Sensor

- 连接到DHT传感器很简单，它们具有0.1“英寸的标准间距引脚，因此可以很容易将它们插到面包板上。他们均有四个管脚:
  - VCC管脚，可以用红线连接到3.3 - 5V电源。注意有时 3.3V 电源不够，在这种情况下可尝试用5V电源。
  - 数据输出管脚，可以用白色或黄色线连接到控制器数字管脚。
  - 引脚3，由于未被使用，直接忽略即可。
  - 接地，可以用黑线接到控制板接地。
- 注意需要在 VCC 和数据引脚之间放置一个 10 kΩ电阻，作为数据线上的中等强度上拉电阻。Arduino内置了可以打开的上拉，但由于阻值大，大约20-50K，强度较弱。

- Luckily it is trivial to connect to these sensors, they have fairly long 0.1“-pitch pins so you can plug them into a breadboard. They have four pins:
  - VCC - Connect it to 3.3 - 5V power using red wire. Sometime 3.3V power isn't enough in which case try 5V power.
  - Data out – Connect it using white or yellow wire to the digital pin of the MCU.
  - Pin 3, Simply ignore it, its not used
  - Ground – Connect using black wire
- It is suggested to place a 10 kΩ resistor between VCC and the data pin, to act as a medium-strength pull up on the data line. The Arduino has built in pullups you can turn on but they're very weak due to higher resistance, about 20-50K

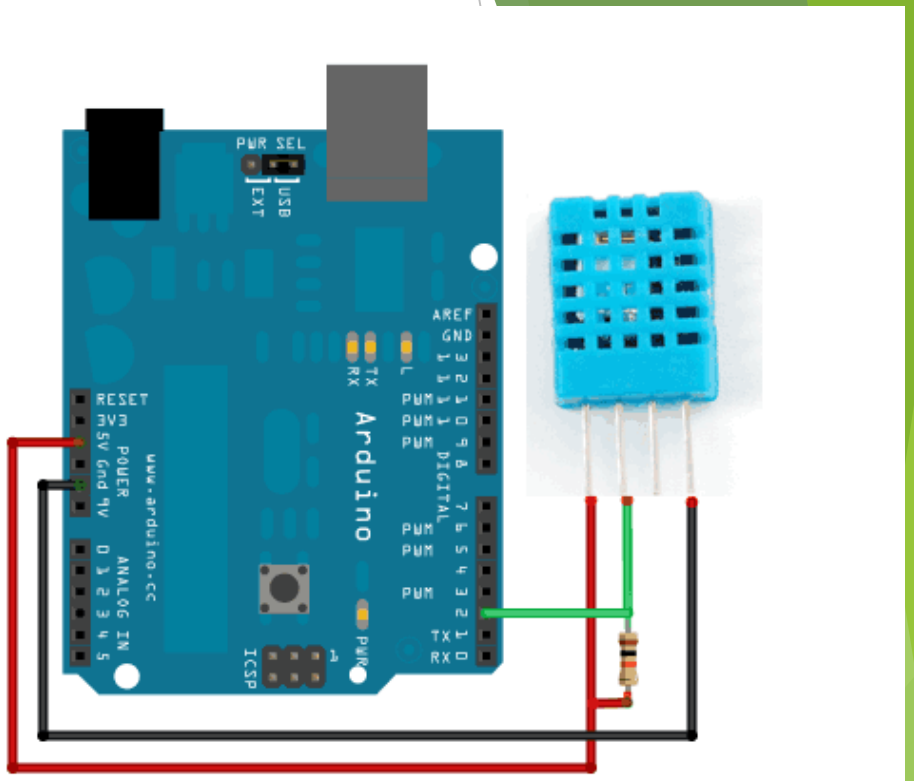
温湿度传感器
Temperature and Humidity Sensor

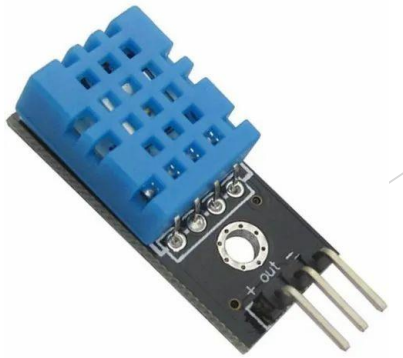
- 尽管不明显，直接使用DHT时，建议在电源与地之间并一个100nF的电容进行电源滤波。

  Although implicitly, it is recommend to have a shunt capacitor of 100nF between the voltage source and ground for power filtering.

- 当然，读者也可以买市面上已集成电阻、电容及LED指示灯的板子直接使用。此时，往往只把有用的三只脚拉出，并且板子上也有标识，读者不难辨认。连好之后，可以用Adafruit公司提供的dht库进行编程读取数据。

  Also, readers can buy boards with resistors, capacitors and LED indicators already integrated from the market. In this case, only the three useful pins are available. There are marks on the board indicating the functionalities of the pins, which are not difficult for readers to identify. After connecting the pins, you can read the data by using the dht library provided by Adafruit.





继电器
Relay

- 继电器是使用电磁场将可移动触点从打开位置移动到关闭位置或者相反的机电设备。

  Relays are electromechanical devices that use an electromagnet to operate a pair of movable contacts from an open position to a closed position or vice versa.

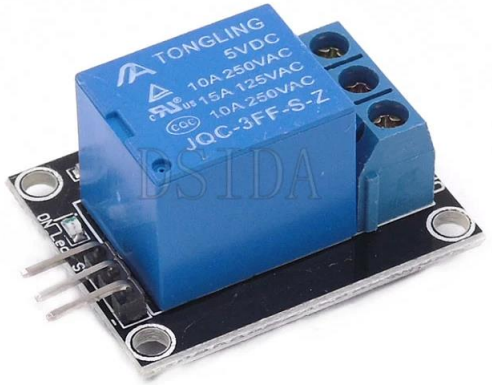
- 机电继电器是一种输出设备（执行器），具有多种形状、尺寸和设计，在电子电路中具有多种用途和应用。由于操作继电器线圈需要相对较小的功率，继电器可用于允许低功率电子或计算机类型的电路将相对较高的电流或电压“打开”或“关闭”，如电机、加热器、灯或 AC 电路，这些电路本身会消耗更多的功率。

  The electro-mechanical relay is an output device (actuator) which come in a whole host of shapes, sizes and designs, and have many uses and applications in electronic circuits. Since it takes a relatively small amount of power to operate the relay coil, the electrical relays can be used to allow low power electronic or computer type circuits to switch relatively high currents or voltages both “ON” or “OFF”, for instance, motors, heaters, lamps or AC circuits which themselves can draw a lot more electrical power.

继电器
Relay

- 市面上常见的用于Arduino的继电器为由通灵公司生产的JQC-3FF系列，以单路或双路居多。常见的模块为JQC-3FF-S-Z，其中S代表封装方式，Z代表接触方式。由于单独的一个模块不便使用，市场上提供的以右图继电器成品电路为主。

The commonly-used relays for Arduino on market are produced by the TongLing company with series JQC-3FF. It could be single or double. The relay module are usually of the type JQC-3FF-S-Z, where S denotes the method of sealing and Z denotes the contact form. Since a standalone module is inconvenient to use, the products on market are the manufactured circuits ready to use.

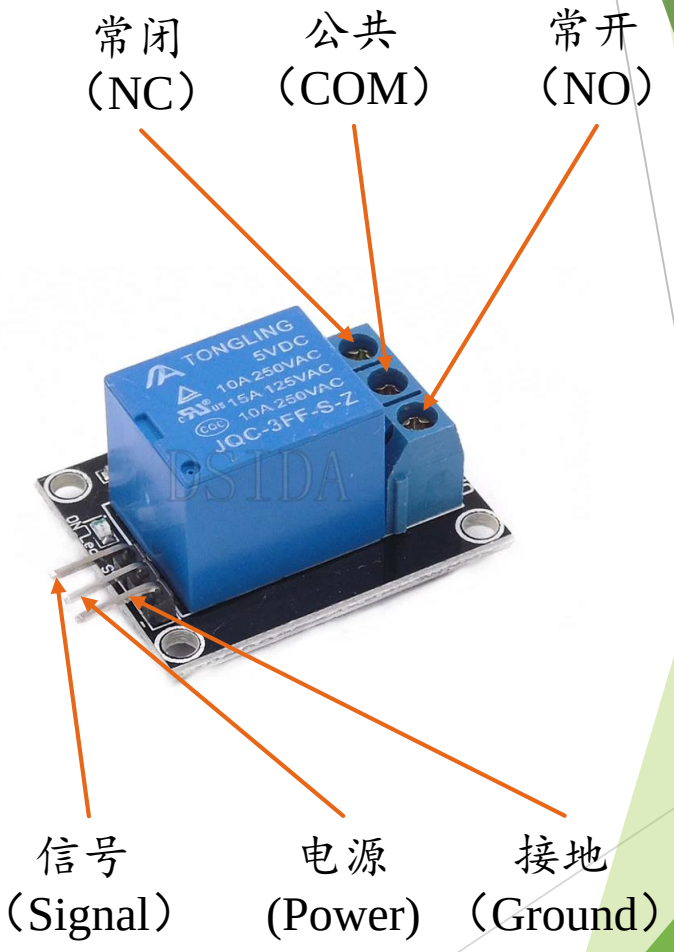


继电器
Relay

- 这些继电器产品一般均符合国际安全标准，如控制部分与负载部分隔离。一般均采用双面电路板设计，并有LED灯展示相应的状态。

  These relay products are generally in line with international safety standards, namely, control area and the load area has a separate slot. They tend to be double-sided circuit board design and LED to indicate different status.

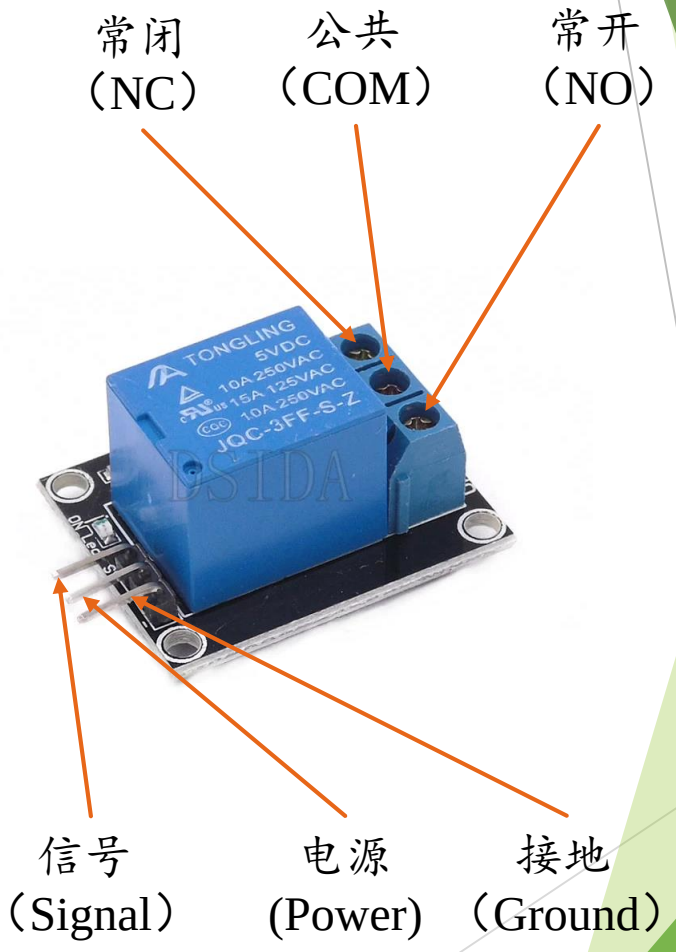
- 模块接口输出部分的定义如下：
  - NO - 常开
  - COM-公共
  - NC - 常闭
- Definition of the module interface output Section:
  - NO - Normally Open
  - COM - Common
  - NC - Normally Closed



继电器
Relay

- 模块接口输入部分定义：
  - VCC：接电源正极（根据继电器电压）
  - GND：接电源负极或地
  - IN：继电器模块信号触发（低电平有效）
  - 高低的意思：高电平触发是指触发端有正电压或达到触发电压时，继电器吸合。低电平触发是指当触发端为0V电压或电压为0V时吸合继电器即可触发。

- Definition of module interface input section:
  - VCC: Connect power supply positive in accordance to the relay voltage
  - GND: Connect ground or power supply negative
  - I N: relay module signal trigger (low level active)
  - High and low meaning: High-level trigger means when the trigger side has a positive voltage or to reach the trigger voltage, the relay is sucked. Low-level trigger means when the trigger side of the 0V voltage or voltage can be triggered when the relay is pulled.



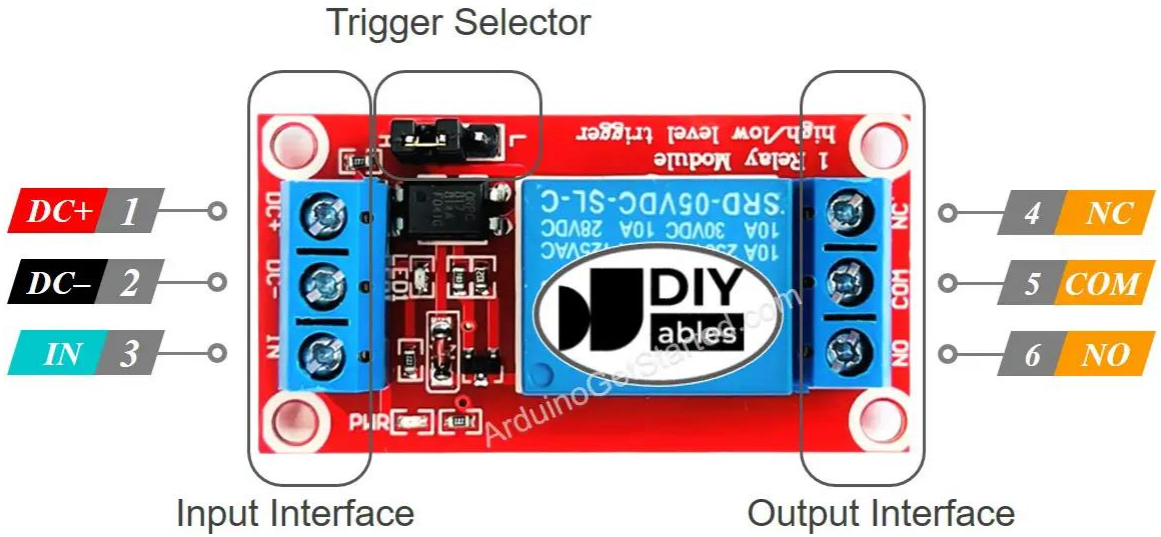
继电器
Relay

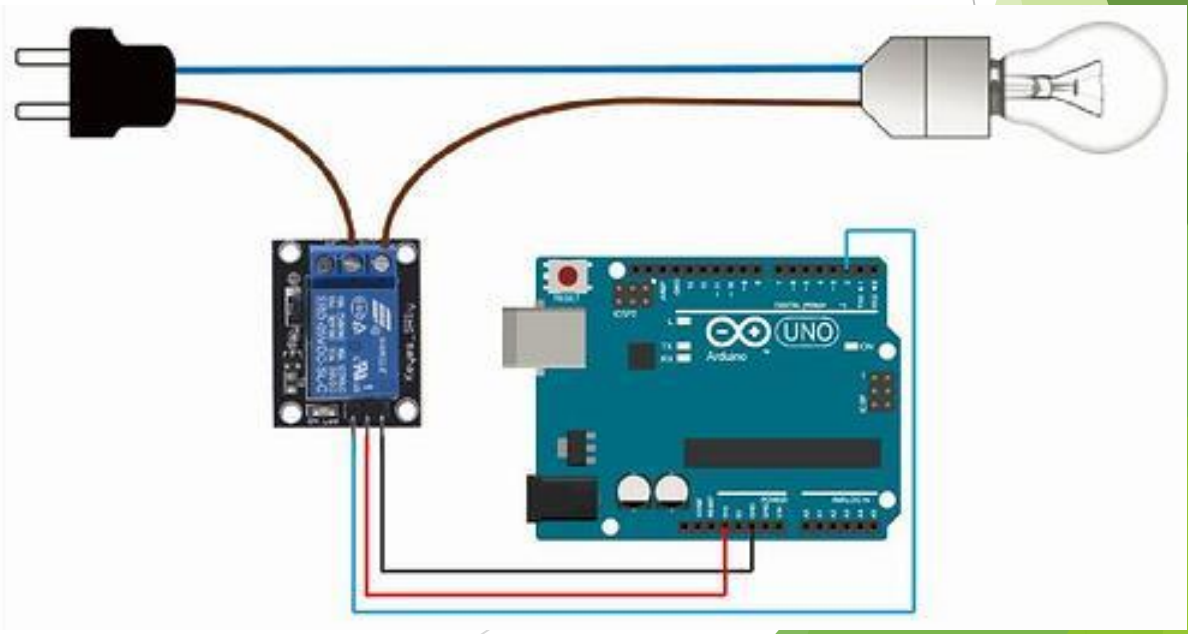
- 一些产品板子上可能有跳线。跳线与LOW短接时为低电触发，跳线与HIGH短接时为高电平触发。

  Some products may have jumpers on the board. When the jumper is short-circuited with LOW, it is low-voltage triggered, and when the jumper is short-circuited with HIGH, it is high-level triggered.

- 典型的负载接法如右图所示：

  The typical load connection is shown in the figure on the right:

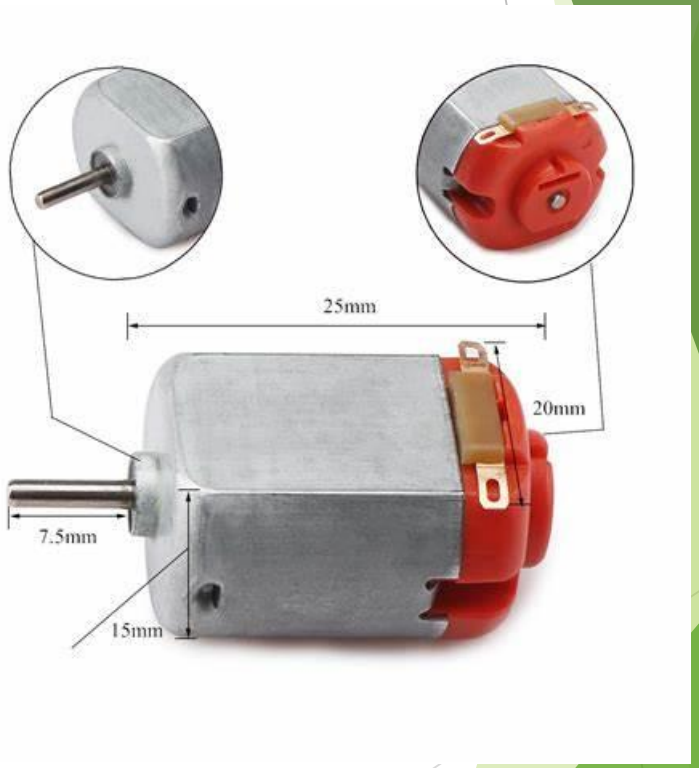




直流电机
DC Motor

- 直流电动机或直流马达是最常见的电动机类型，我们常用的是130小马达。直流电机通常只有两根接线，由于当以不同的方式接电源正负极时，仅电机的旋转方向相反，因此，一般没有显式地区分接线的正负极。不过，由于马达需要将一定的电能转化为机械能，因此往往需要特定的驱动电路以满足要求。

  DC motors are the most common motors. A stereotypical one is the micro 130 motor. DC motors usually come with two terminals. When the terminals are wired to the power supply in different ways, it just causes the motor to rotate in different directions without damage. Therefore, there is usually no explicit distinct between the polarity of the terminals. Because the motor needs to convert the electrical power into mechanical power, usually a driving circuit is need for the motor to work properly.

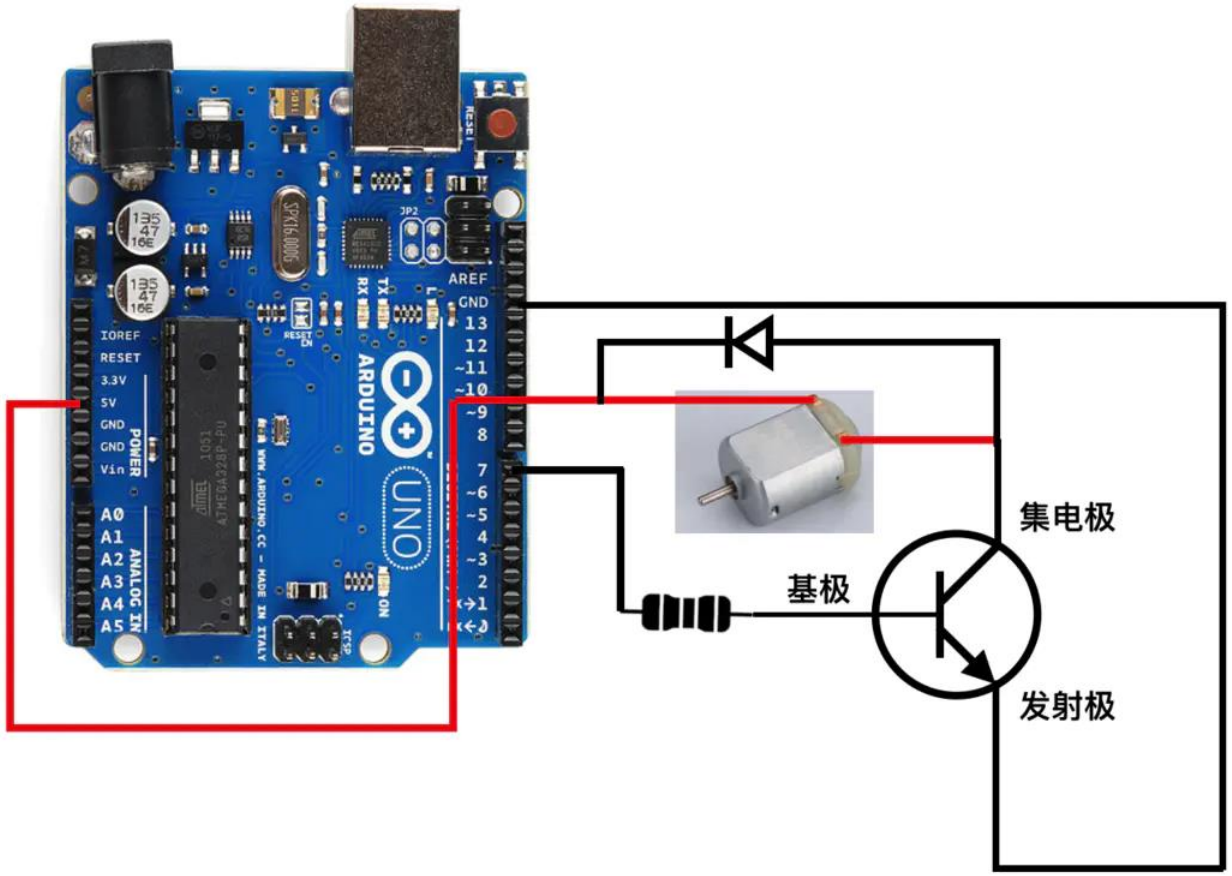


直流电机
DC Motor

- 以130小马达为例，其空载电流一般在100mA左右，负载电流更大，而Arduino Uno或ESP32管脚往往输出电流在20mA左右，若直接接控制板，则有可能损坏电路，因此往往采取放大电路驱动的方式。

  For example, the no-load current for a micro 130 motor requires the current around 100mA. However, both Arduino Uno or ESP32 can only output about 20mA current for pins. Direct connection of motor to the board might damage the circuit. Therefore, amplification circuit is needed to control the DC motor.

- 注意，根据楞次定律，当直流电机线圈在断电瞬间会产生自感电动势，其峰值可能超过三极管所能承受的最大电压， 所以我们需要在直流电机两端并联一个二极管来保护因自感产生的尖峰电压。



伺服电机
Servo Motor

- 伺服电机用在需要精确运动控制的场合。伺服电机由以下部件的组装构成：直流电机、齿轮、电位计和控制电路。伺服电机内部的齿轮组会减慢内部旋转速度，同时增加扭矩。伺服电机中的位置传感器安装在最终档位上，通过微控制器确定转子的当前位置及目标位置。微控制器产生的误差信号用于将转子移动到所需位置。伺服电机可分为位置旋转电机和连续旋转电机。

  The servo motor is used in the case where precise motion control is demanded. The servo motor is constructed from the assembly of the following components; a DC motor, gears, a potentiometer, and a control circuit. The gearing set inside a servo motor will slow down the internal high speed while increasing the torque. The positional sensor in a servo motor is fitted on the final gear. The microcontroller will determine the rotor's current position to the desired position. The error signal generated by the microcontroller is used to move the rotor to the desired position. Servo motors can be categorized into positional rotation motor and continuous rotation motor.

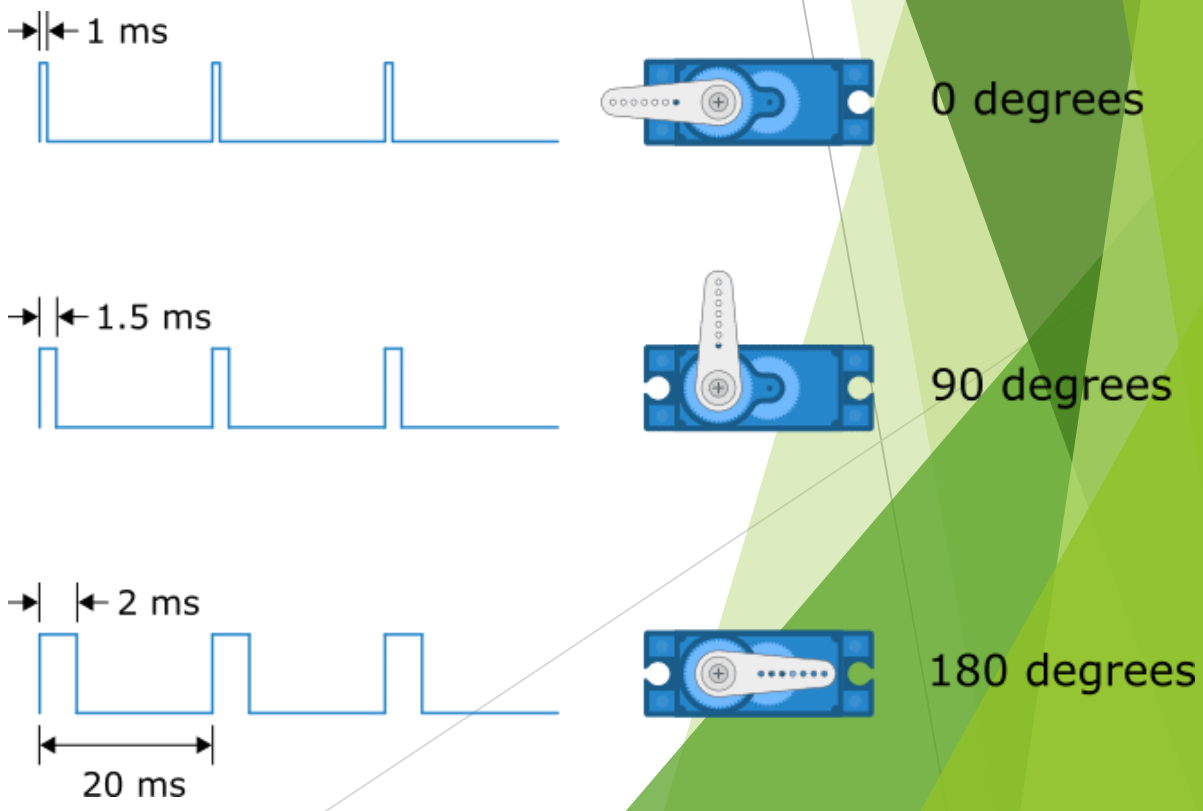
- 位置旋转伺服电机适用于需要适度精确定位的应用。它不提供速度控制或连续旋转。它有一个内置在齿轮组中的物理停止机构，以防止旋转超过180度范围。连续旋转伺服电机可以以不同的速度沿顺时针或逆时针方向连续转动。

  The positional rotation servo motor is fitted into applications where moderate precise positioning is required. It does not provide speed control or continuous rotation. It has an inbuilt physical stop mechanism built into the gear to prevent turning beyond a 180 degrees range.

伺服电机
Servo Motor

- Servo motors are controlled by sending a PWM (pulse-width modulation) signal via the signal line. The width of the pulses determines the position of the output shaft. For example, a signal with a pulse width of 1.5 milliseconds (ms) will cause the servo to move to the neutral position (90 degrees). The min (0 degrees) and max (180 degrees) position typically correspond to a pulse width of 1 ms and 2 ms respectively. Note this can vary slightly between different types and brands of servo motors (e.g. 0.5 and 2.5 ms). Many servos only rotate through about 170 degrees (or even only 90) but the middle position is almost always at 1.5 ms. Servo motors generally expect a pulse every 20 milliseconds or 50 Hz but many rotary actuator based servos work fine in a range of 40 to 200 Hz.

- 伺服电机通过向伺服信号线发送PWM（脉冲宽度调制）信号来控制。脉冲的宽度决定了输出轴的位置。例如，当向舵机发送脉冲宽度为1.5毫秒 (ms) 的信号时，舵机将移动到中立位置（90度）。最小（0 度）和最大（180 度）位置通常分别对应于1毫秒和2毫秒的脉冲宽度。注意，不同类型和品牌的伺服电机之间可能略有不同（例如0.5和2.5毫秒）。许多舵机只能旋转大约170度（甚至只有90度），但中间位置几乎总是基于1.5毫秒。伺服电机通常期望每20毫秒或50 Hz产生一个脉冲，但许多基于旋转执行器的伺服电机在40到200 Hz的范围内工作良好。



伺服电机
Servo Motor

- 伺服电机接线非常简单，通常只需连接三根线：电源、地线和信号线。电源线通常为红色，需要连接到 5 V。但像SG90这样的微型伺服器在空闲时消耗大约10mA，在旋转时会消耗100–250mA，因此您可以直接使用Arduino或ESP32的5 V输出为其供电。但是，在使用多个或更大的伺服电机时需要小心，特别是电机消耗超过300mA，应该使用外部电源以避免损坏电路板。关于使用外部电源的接法可以参考右侧的示意图。

Wiring a servo motor is very easy because you only need to connect three wires: power, ground, and signal. The power wire is typically red and needs to be connected to 5 V. A micro servo like the SG90 consumes around 10 mA when it’s idle and 100 – 250 mA when rotating, so you can power it directly with the 5 V output of the Arduino or ESP32. However, you need to be careful when using multiple or larger servo motors. If your motor(s) consume more than 300 mA you should use an external power supply to avoid damaging the Arduino! See the schematic on the right for using external power supplies.