abc
Basic Connections

Alberto Piganti

ABC: Basic Connections
by Alberto Piganti

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Printing History:

abc
Basic Connections

Important Message:

Your safety is your own responsibility, including proper use of equipment and safety gear, and determining whether you have adequate skill and experience to complete a specific project. In order to show the project steps more clearly, some illustrations do not depict safety precautions or equipment. Electricity and other resources are dangerous unless used properly and with adequate precautions, including safety gear. The projects included in this book are not intended for use by unsupervised children.

Use the instructions and suggestions in ABC: Basic Connections at your own risk. PighiXXX and the author disclaim all responsibility for any resulting damage, injury, or expense.

Dedicated to the people who have always believed in me:
My wife Olga and my mother

Table of Contents

Basic Concepts

Reference

Basic Connections

Basic Connections

Basic Connections

Basic Connections

Basic Connections

Basic Connections

Basic Connections

Pinouts

Bifold

Graphic Symbols

Symbol	Name	Symbol	Name
	Resistor	**PNP**	PNP Transistor
	Trimmer or Potentiometer	**NPN**	NPN Transistor
	Ceramic Capacitor	**P**	P-Channel MOSFET
	Electrolytic Capacitor	**N**	N-Channel MOSFET
	Phototransistor	**TRIAC**	TRIAC
	Photoresistor (LDR)		NTC Thermistor
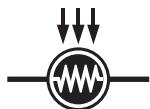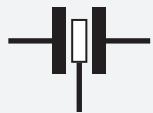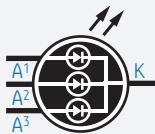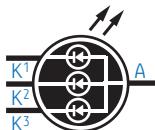
Crystal		LED	
Resonator		Common Cathode RGB LED	
Silicon Diode		Common Anode RGB LED	
Zener Diode		Bi-Color LED	
Schottky Diode		Bi-Color LED	
IR Emitter		Battery	
IR Detector		Fuse	
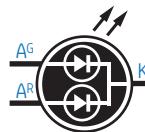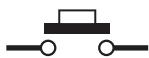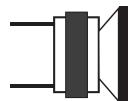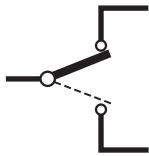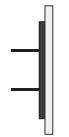
	Pushbutton		Buzzer
	Switch (SPST)		Piezo Buzzer
	Switch (SPDT)		Piezo Element
	Jumper		Speaker
	Transformer		Microphone
	Bridge Rectifier	7805	Device
	Relay		Encoder
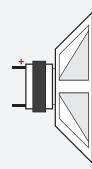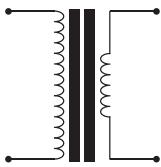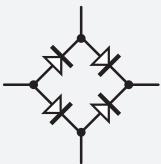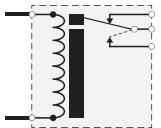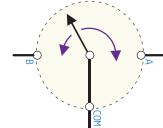
⊕ Supply ⌒ Crossing

☰ Ground ─── Connection

◎ IN/OUT ● Junction

Online Content

You can download additional information, support files and code related each schematic from the URLs on the cloud icons.

0-1.es/xx

We have a web page for this book where we list errata, examples, and any additional information:

abcthebook.com

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contact@abcthebook.com

This book uses American English spelling and the decimal point as the decimal mark. Although the International System of Units prescribes inserting a space between a number and a unit of measurement, such spaces are omitted in this book for aesthetic reasons.

The following conventions are used in this book:

Standard Input/Output Signal

PWM Input/Output Signal

Interrupt Pin

Analog Input/Output Signal

Information
Useful tips about the circuit

Caution
Useful tips about common pitfalls
and limitations of the circuit

Stop
Useful advice to help you avoid
destroying any component

Information
Useful information about the circuit

SEN **Device Pin Name**
Used also in pinout diagrams

SDA **Pin Name**

Acknowledgments

A1

Ohm's Law
Basic Concepts

Ohm's law is one of the most fundamental relation-ships found in electric circuits: for a given resi-stance, current is directly proportional to volta-ge. In other words, if the voltage through a circuit with a fixed resistance increases, the current in-creases. If the voltage decreases, the current de-creases as well. Ohm's law is expressed with a simple mathematical formula:

$$V = I \times R$$

Where **V** stands for voltage (in volts), **I** stands for current (in amperes), and **R** stands for resistance (in ohms). Ohm's law is very useful because it lets you calculate an unknown voltage, current, or resi-stance. If you know two of these three quantities you can calculate the third.
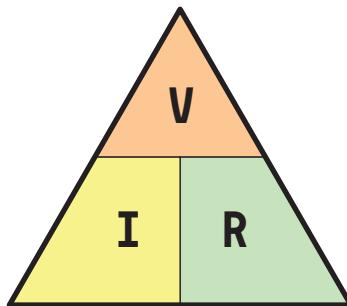
Known values	Resistance (R)	Current (I)	Voltage (V)	Power (P)
Current & Resistance			$V=I \times R$	$P=I^2 \times R$
Voltage & Current	$R=V/I$			$P=V \times I$
Power & Current	$R=P/I^2$		$V=P/I$	
Voltage & Resistance		$I=V/R$		$P=V^2/R$
Power & Resistance		$I=\sqrt{P/R}$	$V=\sqrt{P \times R}$	
Voltage & Power	$R=V^2/P$	$I=P/V$		
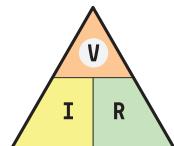
Ohm's Law
Basic Concepts
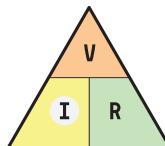
It is easier to remember this Ohm's law relationship by using pictures. Here the three quantities of **V**, **I** and **R** have been superimposed onto a triangle (called the Ohm's Law Triangle). This arrangement represents the position of each quantity within the Ohm's law formulas, making it easier to remember.
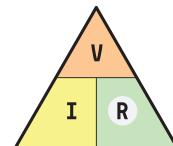
Transposing the standard Ohm's Law equation above will give us the following combinations of the same equation:
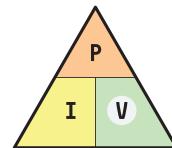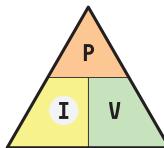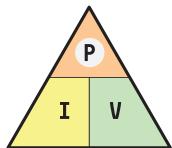
$$V = I \times R \qquad I = \frac{V}{R} \qquad R = \frac{V}{I}$$

Ohm's Law
Basic Concepts
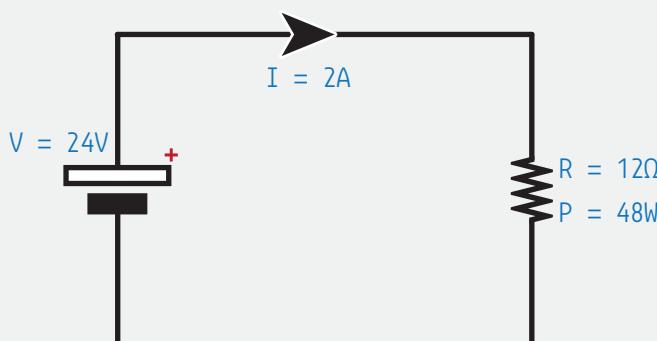
Electric Power (**P**) is the rate at which energy is absorbed or produced within a circuit. Electric power is measured in watts (**W**), that is, joules per second. A source of energy will supply power while the connected load absorbs it. A light bulb, for instance, would absorb power and convert it into both heat and light. The higher its value or rating in watts, the more electrical power it is likely to demand.

$$P = I \times V \qquad I = \frac{P}{V} \qquad V = \frac{P}{I}$$

I = 2A

V = 24V

R = 12Ω
P = 48W
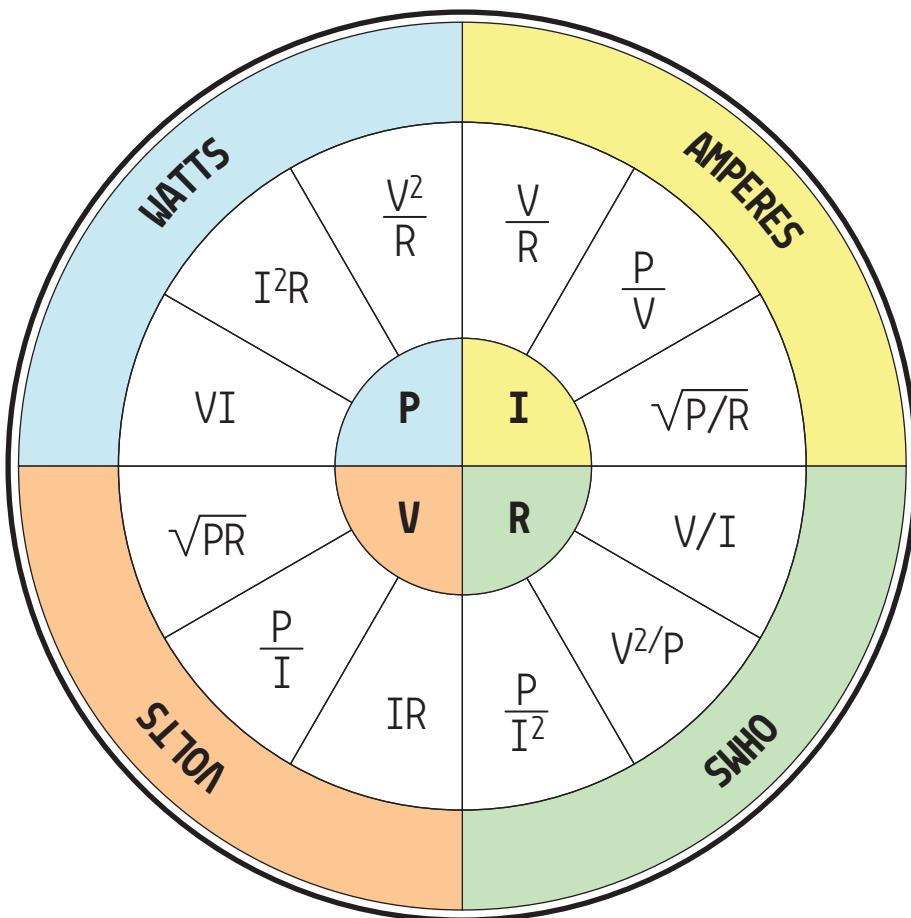
Example test circuit
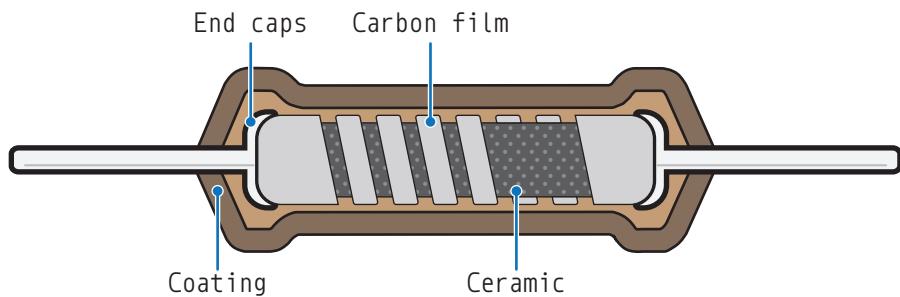
Ohm's Law
Pie Chart Reference

WATTS — AMPERES — VOLTS — OHMS

Center:
- P
- I
- V
- R

WATTS (P):
$$\frac{V^2}{R}$$
$$I^2R$$
$$VI$$

AMPERES (I):
$$\frac{V}{R}$$
$$\frac{P}{V}$$
$$\sqrt{P/R}$$

VOLTS (V):
$$\sqrt{PR}$$
$$\frac{P}{I}$$
$$IR$$

OHMS (R):
$$V/I$$
$$V^2/P$$
$$\frac{P}{I^2}$$

Resistors
Basic Concepts

Conductors are a materials that allow current to flow through them and insulators are materials that don't. The key factor that determines whether a material is a conductor or an insulator is how easily its atoms give up electrons to move charge along. Most atoms are very attached to their outermost electrons, and are therefore good insulators. But some atoms don't, making them good conductors.

End caps   Carbon film

Coating   Ceramic

If a conductor and an insulator are mixed together, the resulting material would not conduct current very well. Such a material would have an inherent resistance, resisting the flow of current through it. The degree to which the material resists current flow depends on its exact mixure of elements. A conducting material such as carbon might be mixed with an insulating material such as ceramic. If the mix is mostly carbon, the resistance of the mixture will be low. Whereas if the mix is mostly ceramic, its resistance will be high.

Resistors
Basic Concepts

Resistance is measured in ohms, represented by the Greek letter omega (Ω). The ohm is defined as the amount of resistance required to allow one ampere of current to flow when one volt of potential is applied to the circuit. In other words, if you connect a 1-ohm resistor across the terminals of a 1-volt battery, one amp of current will flow through the resistor.

4.7kΩ

In schematic diagrams, resistors are represented by a jagged line, with its resistance value typically written next to the resistor symbol.

The abbreviations k (for kilo) and M (for mega) are used for thousands and millions of ohms. Thus, a 1,000 ohm resistance is written as 1 kΩ, and a 1,000,000 ohm resistance is written as 1 MΩ.
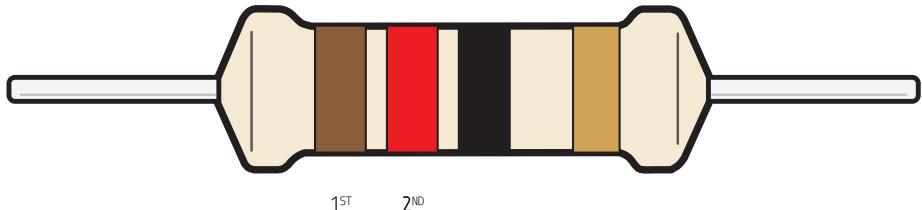
The resistance value of a resistor can be determined by examining the color codes that are painted as stripes on its outer surface. These stripes indicate its resistance value in ohms and its tolerance, which indicates the maximum variation of the real resistance value compared to the value represented by the stripes.

E24 Resistors
Color Code

	1ST Digit	2ND Digit	Multiplier	Tolerance
Black	0	0	x1	
Brown	1	1	x10	
Red	2	2	x100	
Orange	3	3	x1k	
Yellow	4	4	x10k	
Green	5	5	x100k	
Blue	6	6	x1M	
Violet	7	7		
Gray	8	8		
White	9	9		
Gold			x0.1	±5%
Silver				±10%

R1

E24 Resistors
Common Standard Values

1Ω	10Ω	100Ω	1kΩ	10kΩ	100kΩ	1MΩ
1.2Ω	12Ω	120Ω	1.2kΩ	12kΩ	120kΩ	1.2MΩ
1.5Ω	15Ω	150Ω	1.5kΩ	15kΩ	150kΩ	1.5MΩ
1.8Ω	18Ω	180Ω	1.8kΩ	18kΩ	180kΩ	1.8MΩ
2.2Ω	22Ω	220Ω	2.2kΩ	22kΩ	220kΩ	2.2MΩ
2.7Ω	27Ω	270Ω	2.7kΩ	27kΩ	270kΩ	2.7MΩ
3.3Ω	33Ω	330Ω	3.3kΩ	33kΩ	330kΩ	3.3MΩ
3.9Ω	39Ω	390Ω	3.9kΩ	39kΩ	390kΩ	3.9MΩ
4.7Ω	47Ω	470Ω	4.7kΩ	47kΩ	470kΩ	4.7MΩ
5.6Ω	56Ω	560Ω	5.6kΩ	56kΩ	560kΩ	5.6MΩ
6.8Ω	68Ω	680Ω	6.8kΩ	68kΩ	680kΩ	6.8MΩ
8.2Ω	82Ω	820Ω	8.2kΩ	82kΩ	820kΩ	8.2MΩ
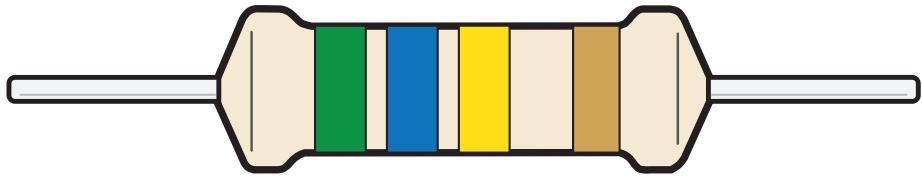
Partial list, full version available online

R2

E48 Resistors
Color Code
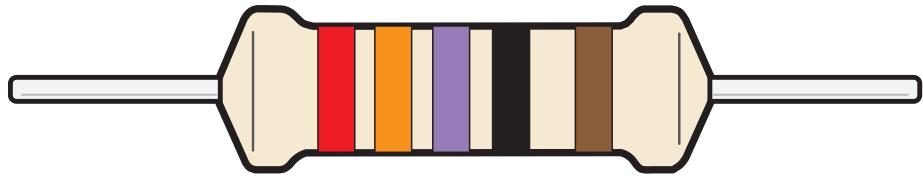
	1ST Digit	2ND Digit	Multiplier	Tolerance
Black	0	0	x1	
Brown	1	1	x10	
Red	2	2	x100	±2%
Orange	3	3	x1k	
Yellow	4	4	x10k	
Green	5	5	x100k	
Blue	6	6	x1M	
Violet	7	7		
Gray	8	8		
White	9	9		
Gold			x0.1	±5%
Silver			x0.01	±10%

R3

E96/E192 Resistors
Color Code

	1ST Digit	2ND Digit	3RD Digit	Multiplier	Tolerance
Black	0	0	0	x1	
Brown	1	1	1	x10	±1%
Red	2	2	2	x100	±2%
Orange	3	3	3	x1k	
Yellow	4	4	4	x10k	
Green	5	5	5	x100k	±0.5%
Blue	6	6	6	x1M	±0.25%
Violet	7	7	7	x10M	±0.10%
Gray	8	8	8		
White	9	9	9		
Gold				x0.1	±5%
Silver				x0.01	±10%
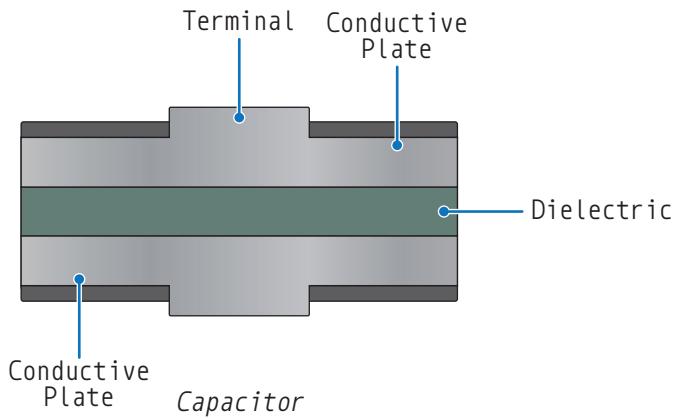
Capacitors
Basic Concepts

Capacitors are components that that store electric energy as an electric field. They consist of two plates made of a conducting material such as silver or aluminum, separated by a thin insulating material such as Mylar or ceramic. The two conducting plates are connected to terminals so that a voltage can be applied across them.

Terminal   Conductive Plate

Dielectric

Conductive Plate

Capacitor

Because the two plates are separated by a dielectric, that is, an electrical insulator that can be polarized by an electric field, a closed circuit is not formed. Nevertheless, current flows for an instant. When the voltage from a source such as a battery is connected, the negative terminal of the battery immediately begins to push electrons toward one of the plates.
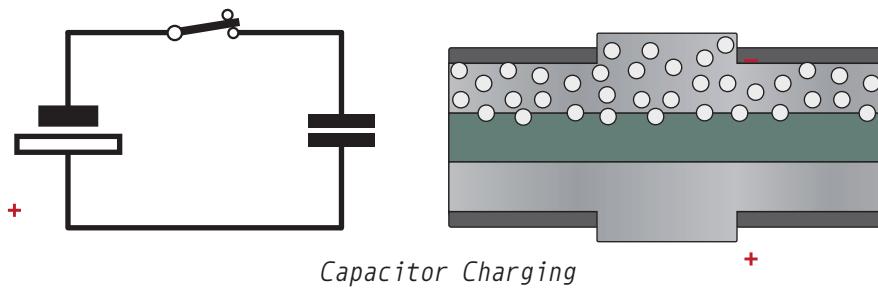
Capacitors
Basic Concepts

At the same time, the positive side of the battery voltage begins to pull electrons (negative charges) away from the second plate. The electric field that builds up between the two plates allows current to flow. As the plate on the negative side of the circuit fills with electrons, the electric field created by them push the electrons away from the plate on the other side of the dielectric, toward the positive side of the battery voltage.

Capacitor Charging

As current flows, the negative plate of the capacitor builds up an excess of electrons, whereas the positive side develops a corresponding deficiency of electrons. At the same time, the voltage between the two plates increases proportionally to the difference in charge between the two plates.
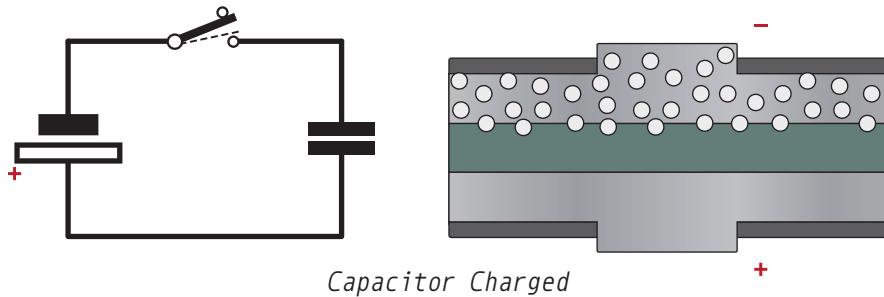
The voltage continues to increase until the capacitor voltage equals the battery voltage. Once they are the same, current stops flowing through the circuit, and the capacitor is said to be charged.
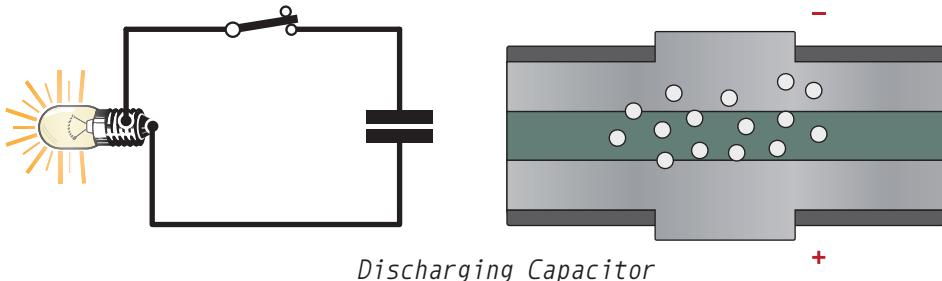
Capacitors
Basic Concepts

Once the capacitor has been charged it will acquire the same voltage as the battery, and the charge will remain in the capacitor even when disconnected. The amount of charge capacitors can store is proportional to the area of their plates.

Capacitor Charged

When a charged capacitor is connected to a circuit, the voltage across its plates will drive current through the circuit, discharging the capacitor.

Discharging Capacitor
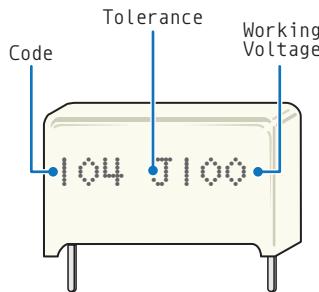
Capacitors
Basic Concepts

Capacitance is the electrical property of a capacitor that defines its ability to store an electric charge onto its two plates, with the unit of capacitance being the farad (**F**). A 1-farad capacitor can store 1 coulomb of charge at 1 volt. A coulomb is 6.25e18 (6.25 billion billion) electrons. Based on this definition, one ampere represents a rate of electron flow of 1 coulomb of electrons per second.

As in the case of resistors, capacitors also have a manufacturing tolerance for their capacitance value.
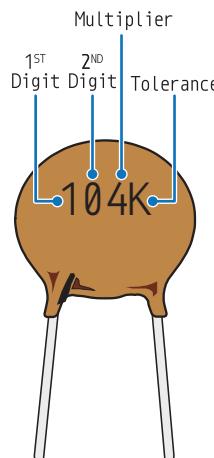
If there is enough room on the package, most manufacturers print the capacitance value directly on the capacitor along with other information such as the voltage rating and the tolerance.

R4

Capacitors
Markings

Multiplier	Multiply by
0	1
1	10
2	100
3	1,000
4	10,000
5	100,000
8	0,01
9	0,1

Multiplier

1ST Digit 2ND Digit Tolerance

104K

$10 \times 10,000 = 100,000pF$
$100,000pF = \mathbf{0.1\mu F\ \pm 10\%}$

Letter	Tolerance >10pF	Tolerance <10pF
B		±0.1pF
C		±0.25pF
D		±0.5pF
F	±1%	±1pF
G	±2%	±2pF
H	±3%	
J	±5%	
K	±10%	
M	±20%	

Conversion Table
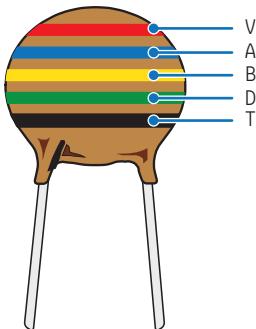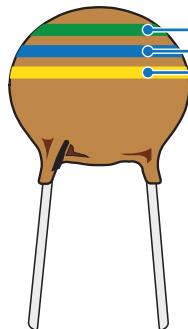
picofarads pF	nanofarads nF	microfarads μF
1	0.001	0.000001
10	0.01	0.00001
100	0.1	0.0001
1,000	1	0.001
10,000	10	0.01
100,000	100	0.1
1,000,000	1,000	1
10,000,000	10,000	10
100,000,000	100,000	100

R5

Capacitors
Color Code

Type	Capacitor Type
J	Dipped tantalum
K	Mica
L	Polyester
M	Electrolytic, 4-band
N	Electrolytic, 3-band
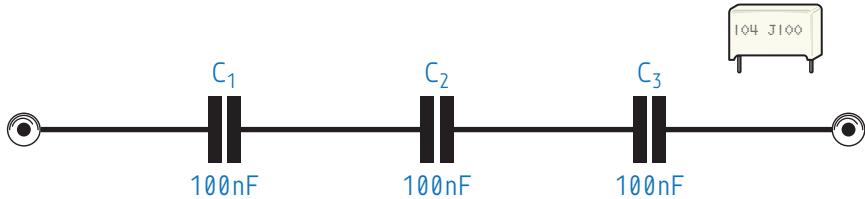
	A	B	D	T	T	V				
	Digit A	Digit B	Multiplier	Tolerance >10pF	Tolerance <10pF	Voltage Rating				
						J	K	L	M	N
Black	0	0	x1	±20%	±2pF	4	100		10	10
Brown	1	1	x10	±1%	±0.1pF	6	200	100	1.6	
Red	2	2	x100	±2%	±0.25pF	10	300	250	4	35
Orange	3	3	x1k	±3%		15	400		40	
Yellow	4	4	x10k	±4%		20	500	400	6.3	6
Green	5	5	x100k	±5%	±0.5pF	25	600		16	15
Blue	6	6	x1M			35	700	630		20
Violet	7	7				50	800			
Gray	8	8	x0.01	+80% −20%			900		25	25
White	9	9	x0.1	±10%	±1pF	3	1000		2.5	3
Gold			x0.1	±5%			2000			
Silver			x0.01	±10%						

A4

Components in Series
Capacitors

C_1

C_2

C_3

100nF

100nF

100nF
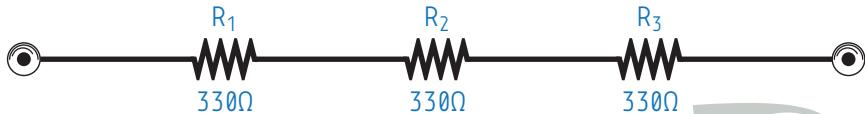
$$C_{TOTAL} = \cfrac{1}{\cfrac{1}{C_1} + \cfrac{1}{C_2} + \cfrac{1}{C_3}}$$

$$C_{TOTAL} = \cfrac{1}{\cfrac{1}{100} + \cfrac{1}{100} + \cfrac{1}{100}}$$

$$C_{TOTAL} = \mathbf{33.33nF}$$

Resistors

R_1

R_2

R_3

330Ω

330Ω

330Ω

$$R_{TOTAL} = R_1 + R_2 + R_3$$

$$R_{TOTAL} = 330+330+330$$
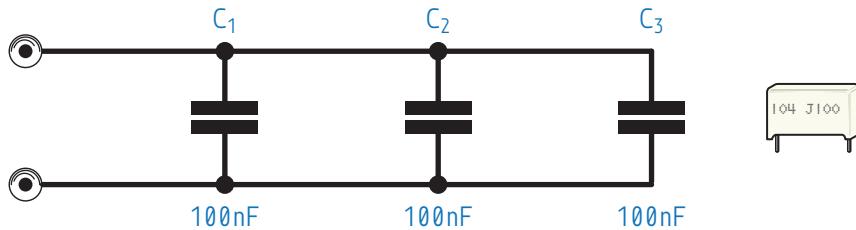
$$R_{TOTAL} = \mathbf{990Ω}$$

A5

Components in Parallel
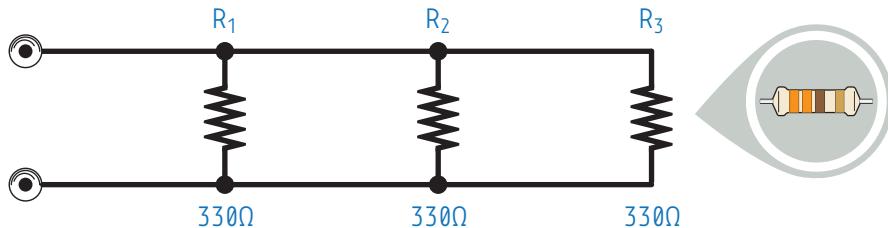
Capacitors

$$C_{TOTAL} = C_1 + C_2 + C_3 \qquad C_{TOTAL} = 100+100+100$$

$$C_{TOTAL} = \textbf{300nF}$$

Resistors

$$R_{TOTAL} = \cfrac{1}{\cfrac{1}{R_1} + \cfrac{1}{R_2} + \cfrac{1}{R_3}} \qquad R_{TOTAL} = \cfrac{1}{\cfrac{1}{330} + \cfrac{1}{330} + \cfrac{1}{330}}$$
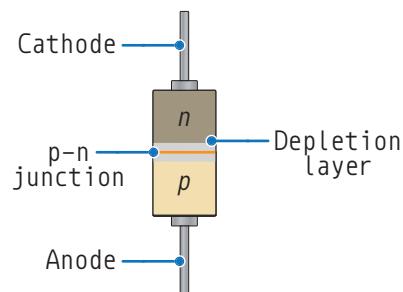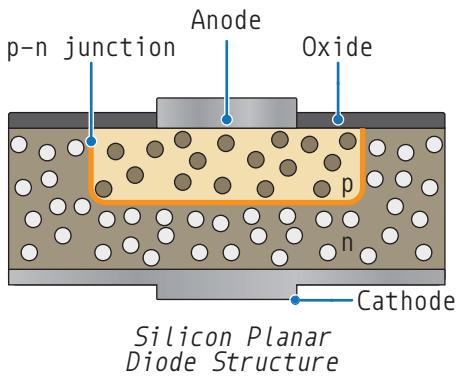
$$R_{TOTAL} = \textbf{110}\boldsymbol{\Omega}$$

Diodes
Basic Concepts

Diodes are components made from a combination of a p-type and n-type semiconductor material, most commonly silicon.

Silicon Planar Diode Structure

The lead attached to the n-type semiconductor is called the cathode. Thus, the cathode is the negative side of the diode. Alternatively, the positive side of the diode, that is, the lead attached to the p-type semiconductor, is called the anode.

In the schematic symbol of the diode, the anode is represented as a triangle and the cathode is represented as a bar. You can think of the anode side of the symbol as an arrow that indicates the direction of conventional current flow, from positive to negative.
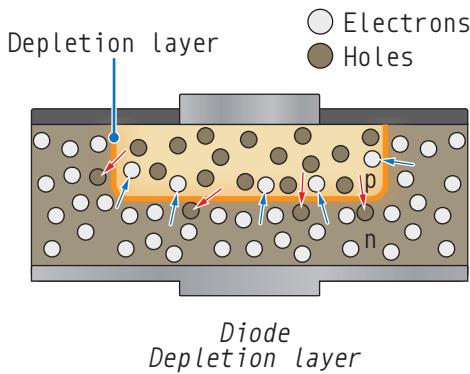
A6

Diodes
Basic Concepts

When p-type and n-type silicon are placed together during the manufacturing process, a junction called p-n junction is created where the p-type and n-type materials meet. Holes, or lack of electrons, close to the junction in the p-type silicon are attracted into negatively charged n-type material at the other side of the junction.

Depletion layer

○ Electrons
● Holes

Diode
Depletion layer
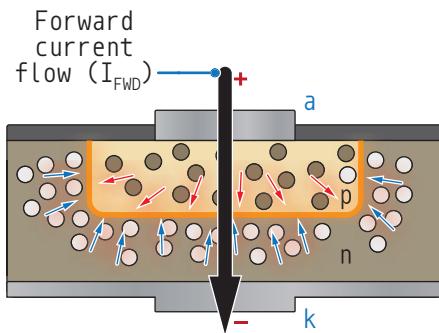
At the same time, electrons close to the junction in the n-type silicon are attracted to the positively charged p-type silicon. The recombination of holes and electrons produces a narrow region at the junction called the depletion layer.
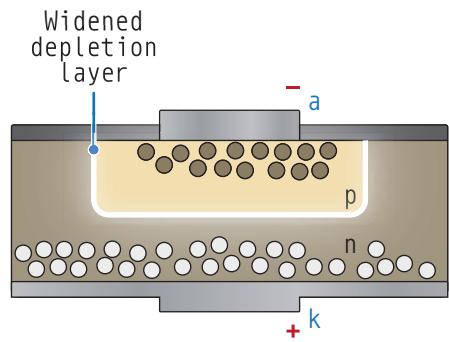
Diodes
Basic Concepts

When a voltage source is connected to a diode such that the positive side of the voltage source is on the anode and the negative side is on the cathode, the diode becomes conductive and allows current to flow. This configuration is called forward bias.

Forward current flow (I_{FWD})

+ a

p

n

− k

Diode in Forward Conduction

Widened depletion layer

− a

p

n

+ k

Reverse-Biased Diode

If the direction of the voltage is reversed, when connecting the positive side to the cathode and the negative side to the anode, current doesn not flow. In this case, the diode becomes an insulator. This configuration is called reverse bias.
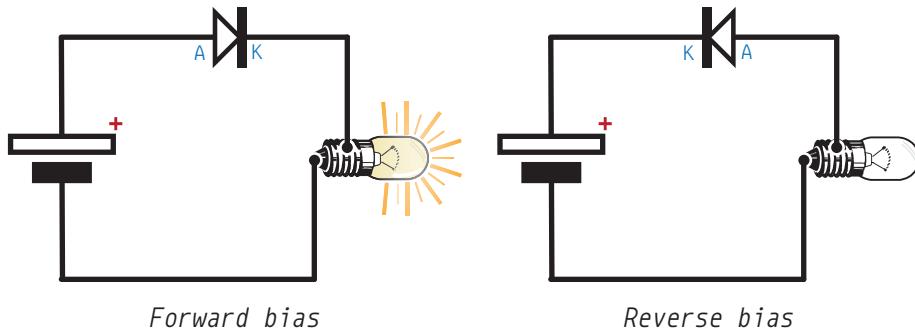
Diodes
Basic Concepts

Forward and reverse bias can be illustrated by connecting a light bulb to a battery with a diode in series. In the circuit on the left, the diode is forward biased, so current flows through the circuit and the light bulb lights up. In the circuit on the right, the diode is reverse biased, so current does not flow and the light bulb remains off.

Forward bias

Reverse bias
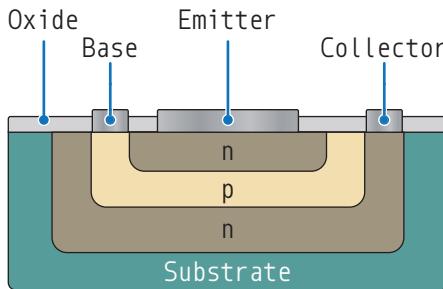
When a diode is connected to a circuit, no current can flow between anode and cathode until the anode is made more positive than the cathode by a forward voltage sufficiently high to overcome the natural reverse potential of the p-n junction. This voltage, called forward voltage drop (V_F), is usually around 0.5V.
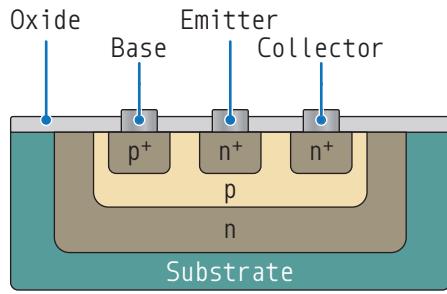
Transistors
Basic Concepts

Transistors similar to diodes but containing a third layer of either n-type or p-type semiconductor on one end. The interface between each of the three regions forms a p-n junction.

Oxide   Emitter   Oxide   Emitter
   Base   Collector   Base   Collector

| n |
| p |
| n |
| Substrate |

Planar transistor structure

| p⁺ | n⁺ | n⁺ |
| p |
| n |
| Substrate |

Lateral planar transistor structure

One way in which transistors are made is by sandwitching a a p-type semiconductor between two n-type semiconductors. This type of transistors are called NPN because they have three regions: n-type, p-type, and n-type.
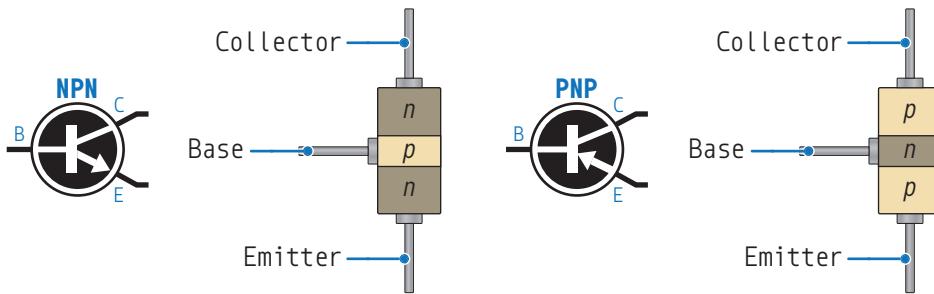
Alternatively, PNP transistors are made by sandwitching an n-type semiconductor between two p-type semiconductors.

Transistors

Basic Concepts

Each of the three regions of semiconductor material in a transistor has a lead attached to it. They are called collector, base and emitter respectivelly.

Collector: Attached to the largest of the semiconductor regions. Current flows through the collector to the emitter as controlled by the base.

Emitter: Attached to the second largest of the semiconductor regions. Current flows from the collector to the emitter when the base voltage allows.
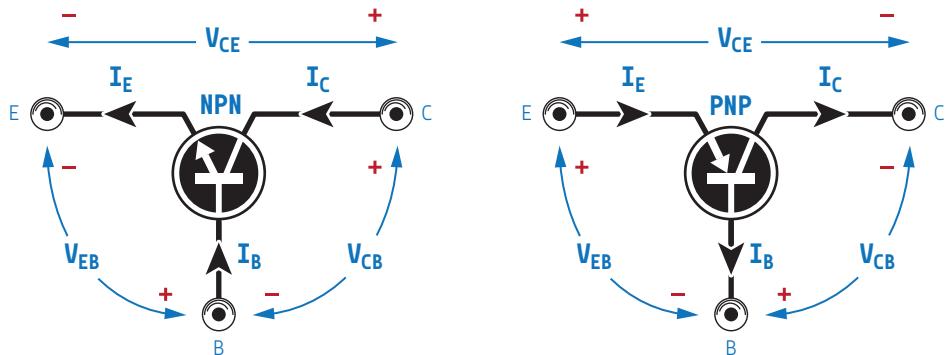
Base: Attached to the middle semiconductor region. This region serves as a valve that controls how much current is allowed to flow through the collector-emitter circuit. When sufficient voltage is applied to the base, current is allowed to flow.

A7

Transistors
Basic Concepts

Transistors are current-regulating devices that act as a current-controlled switches. The amount of current flowing through them varies proportionally with the amount of biasing voltage applied to their base terminal.

The schematic symbols for both transistors have their arrows pointing in the direction of the conventional current flow, between the base terminal and its emitter terminal. The direction of the arrow points from the positive p-type region to the negative n-type region for both transistor types, the same occurs with the standard diode symbol.
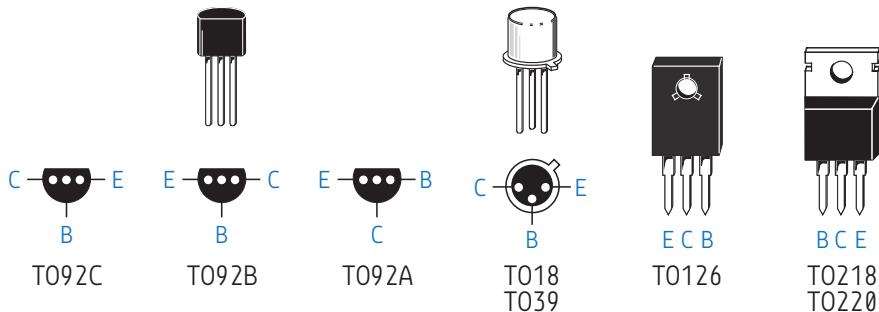
Two diode analogy

Transistors
Basic Concepts

Transistors come in a wide variety of physical packages. Package type is primarily dependent upon the required power dissipation of the transistor, with it physical size being proportional to its maximum power dissipation.

C E	E C	E B	C E	E C B	B C E
B	B	C	B		
TO92C	TO92B	TO92A	TO18 TO39	TO126	TO218 TO220

Note: It is very important to check the datasheet of each transistor since the pinouts are not standardized.

Symbol	Description
V_{CE}	Collector-Emitter Voltage
V_{EB}	Emitter-Base Voltage
V_{CB}	Collector-Base Voltage
I_E	Emitter Current
I_C	Collector Current
I_B	Base Current
hFE	Current Gain

Important transistor characteristics

R6

Transistor Selector

NPN

NAME
V_{CE} I_C
hFE
pins

TIP120
60V   5A
1000
bce

BC338
45V 800mA
100
cbe

BC548
30V 500mA
200
cbe

2N2222
40V 600mA
35
cbe

BC337
45V 800mA
100
cbe

BC547
45V 100mA
420
cbe

BC549
30V 100mA
420
cbe

S8050
30V 700mA
120
ebc

2N4403
40V 200mA
60
ebc

BC546
65V 100mA
420
cbe

2N4403
40V 600mA
30
ebc

2N3904
40V 200mA
60
ebc

S9013
40V 500mA
100
ebc

BC639
80V   1A
100
ecb
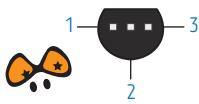
2SD882
60V   3A
200
bce

BD139
80V 1.5A
100
bce

1   3
2

R7

Transistor Selector

PNP

NAME
V_{CE} I_C
hFE
pins

BC640
80V   1A
100
cbe

BC328
25V 800mA
100
cbe

BC327
45V 800mA
100
cbe

S9012
40V 500mA
100
cbe

2N2907
60V 600mA
100
cbe

S9014
50V 500mA
100
ebc

BC558
30V 100mA
420
cbe

BC557
45V 100mA
180
cbe

S8550
20V 700mA
100
cbe

2N3906
40V 200mA
100
cbe

S9012
40V 500mA
100
ebc

BC640
80V   1A
100
ecb

S8050
30V 700mA
120
ebc

BD140
80V 1.5A
100
bce
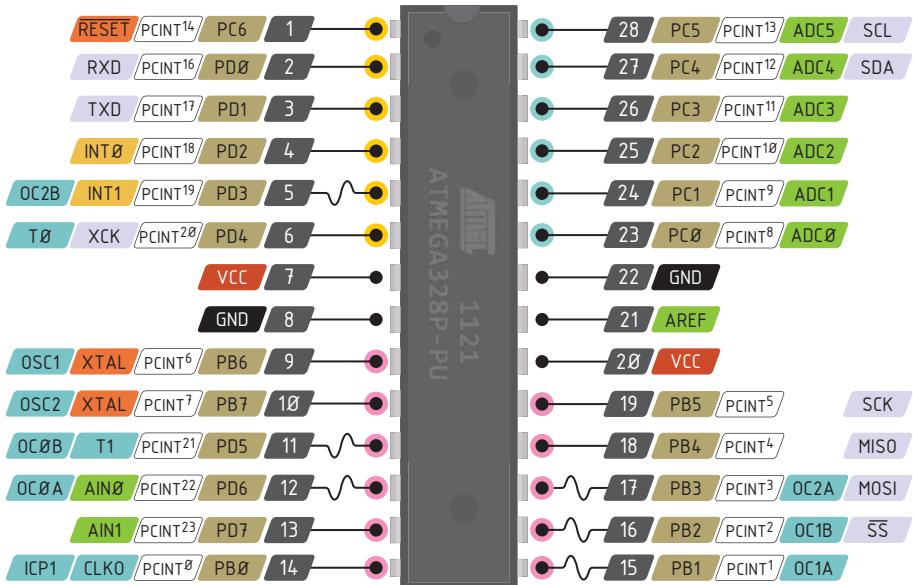
TIP125
60V   5A
1000
bce

1 —●●●— 3

2

ATmega328P
Pinout

⚠ Absolute MAX per pin
40mA, 20mA recommended

Left			Pin		Pin				Right
RESET	PCINT14	PC6	1		28	PC5	PCINT13	ADC5	SCL
RXD	PCINT16	PD0	2		27	PC4	PCINT12	ADC4	SDA
TXD	PCINT17	PD1	3		26	PC3	PCINT11	ADC3	
INT0	PCINT18	PD2	4		25	PC2	PCINT10	ADC2	
OC2B	INT1	PCINT19	PD3	5	24	PC1	PCINT9	ADC1	
T0	XCK	PCINT20	PD4	6	23	PC0	PCINT8	ADC0	
		VCC	7		22	GND			
		GND	8		21	AREF			
OSC1	XTAL	PCINT6	PB6	9	20	VCC			
OSC2	XTAL	PCINT7	PB7	10	19	PB5	PCINT5		SCK
OC0B	T1	PCINT21	PD5	11	18	PB4	PCINT4		MISO
OC0A	AIN0	PCINT22	PD6	12	17	PB3	PCINT3	OC2A	MOSI
	AIN1	PCINT23	PD7	13	16	PB2	PCINT2	OC1B	SS
ICP1	CLK0	PCINT0	PB0	14	15	PB1	PCINT1	OC1A	

ATMEGA328P-PU
1121

🚫 Absolute MAX per pin 200mA
for the entire package

🚫 The total current of each port
power group should not exceed 100mA

🟥	Power
⬛	GND
◼	Physical PIN
🟫	Port PIN
🟩	Analog PIN
🟪	Serial PIN
🟦	PIN Function
🟨	Interrupt PIN
🟧	Control PIN
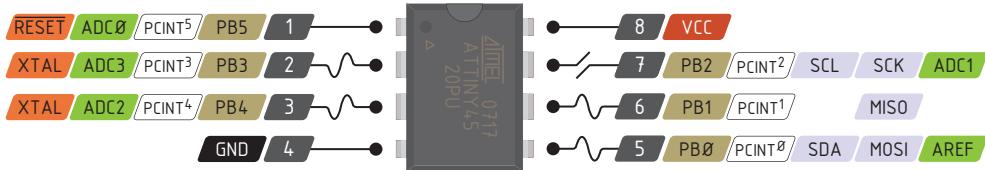
∿ PWM Pin

🔴🟡🔵 Port power group

P2

0-1.es/P2
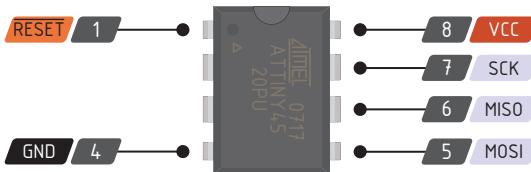
ATtiny85
Simplified Pinout

⚠️ Absolute MAX per pin
10mA, 5mA recommended

RESET	ADC0	PCINT5	PB5	1		8	VCC
XTAL	ADC3	PCINT3	PB3	2		7	PB2	PCINT2	SCL	SCK	ADC1
XTAL	ADC2	PCINT4	PB4	3		6	PB1	PCINT1		MISO
			GND	4		5	PB0	PCINT0	SDA	MOSI	AREF

🚫 Absolute MAX per pin 60mA
for the entire package

ICSP Programming

RESET	1		8	VCC
			7	SCK
			6	MISO
GND	4		5	MOSI

- 🟥 Power
- ⬛ GND
- ⬛ Physical PIN
- 🟫 Port PIN
- 🟩 Analog PIN
- 🟦 Serial PIN
- 🟦 PIN Function
- 🟨 Interrupt PIN
- 🟧 Control PIN
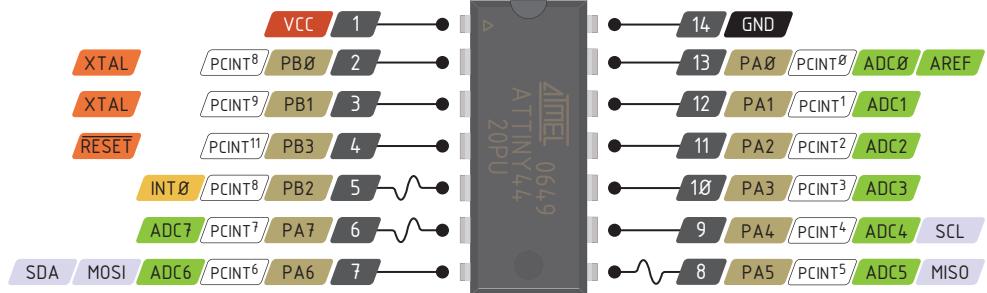
⚡ Interrupt Pin
〰️ PWM Pin

ATtiny84
Simplified Pinout
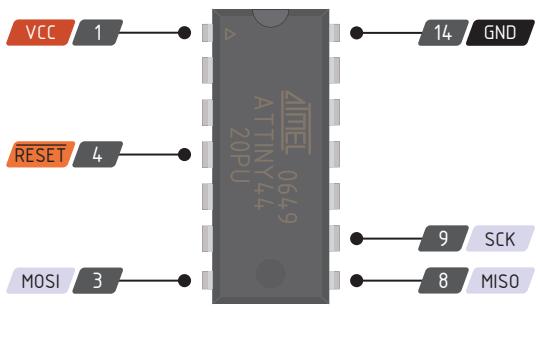
⚠ **Absolute** MAX per pin
10mA, 5mA recommended

	VCC	1	14	GND	
XTAL	PCINT8 PB0	2	13	PA0 PCINT0 ADC0	AREF
XTAL	PCINT9 PB1	3	12	PA1 PCINT1 ADC1	
RESET	PCINT11 PB3	4	11	PA2 PCINT2 ADC2	
	INT0 PCINT8 PB2	5	10	PA3 PCINT3 ADC3	
	ADC7 PCINT7 PA7	6	9	PA4 PCINT4 ADC4	SCL
SDA MOSI	ADC6 PCINT6 PA6	7	8	PA5 PCINT5 ADC5	MISO

ATTINY44 20PU 0649

🚫 **Absolute** MAX per pin 60mA
for the entire package

ICSP Programming

VCC	1		14	GND	
RESET	4				
			9	SCK	
MOSI	3		8	MISO	

ATTINY44 20PU 0649

🟥	Power
⬛	GND
⬛	Physical PIN
🟫	Port PIN
🟩	Analog PIN
🟦	Serial PIN
🟦	PIN Function
🟨	Interrupt PIN
🟧	Control PIN

⌇— PWM Pin

P4
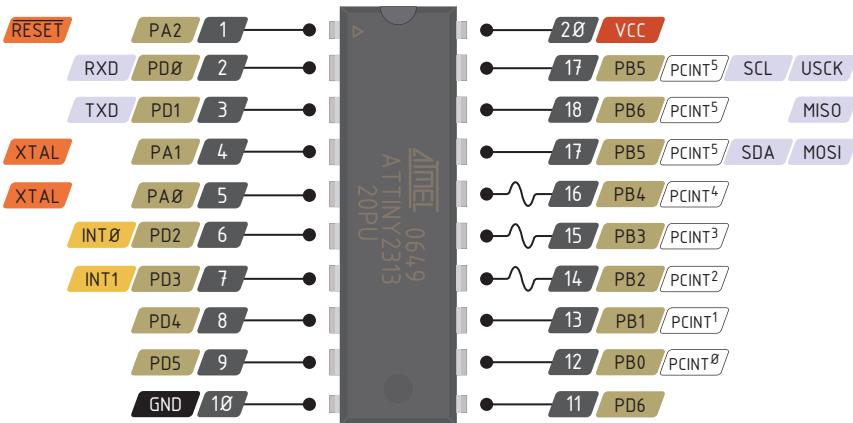
0-1.es/P4

ATtiny2313
Simplified Pinout

⚠ Absolute MAX per pin
10mA, 5mA recommended

RESET	PA2	1
RXD	PD0	2
TXD	PD1	3
XTAL	PA1	4
XTAL	PA0	5
INT0	PD2	6
INT1	PD3	7
	PD4	8
	PD5	9
GND	10	

ATMEL 0649 ATTINY2313 20PU

20	VCC			
17	PB5	PCINT5	SCL	USCK
18	PB6	PCINT5		MISO
17	PB5	PCINT5	SDA	MOSI
16	PB4	PCINT4		
15	PB3	PCINT3		
14	PB2	PCINT2		
13	PB1	PCINT1		
12	PB0	PCINT0		
11	PD6			

🚫 Absolute MAX per pin 60mA
for the entire package

- ▬ Power
- ▬ GND
- ▬ Physical PIN
- ▬ Port PIN
- ▬ Analog PIN
- ▬ Serial PIN
- ▬ PIN Function
- ▬ Interrupt PIN
- ▬ Control PIN
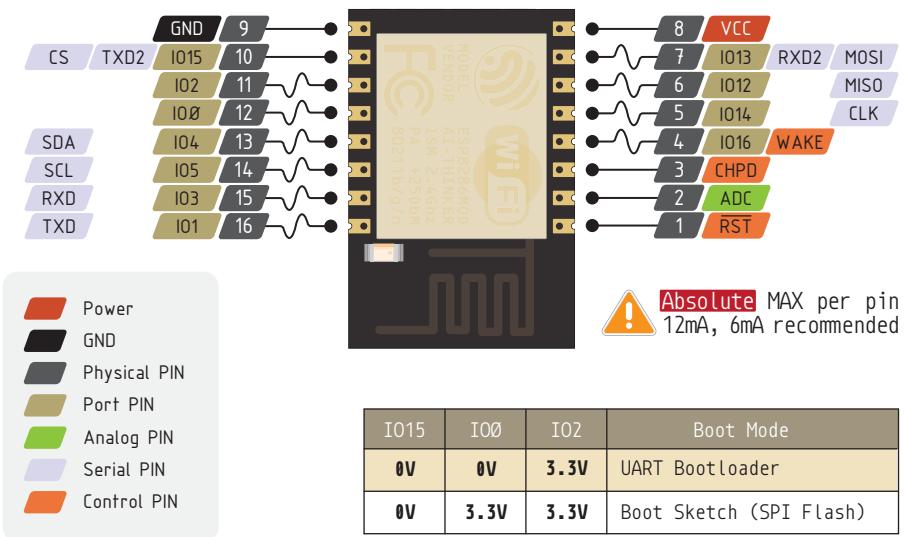
─⏦─ PWM Pin
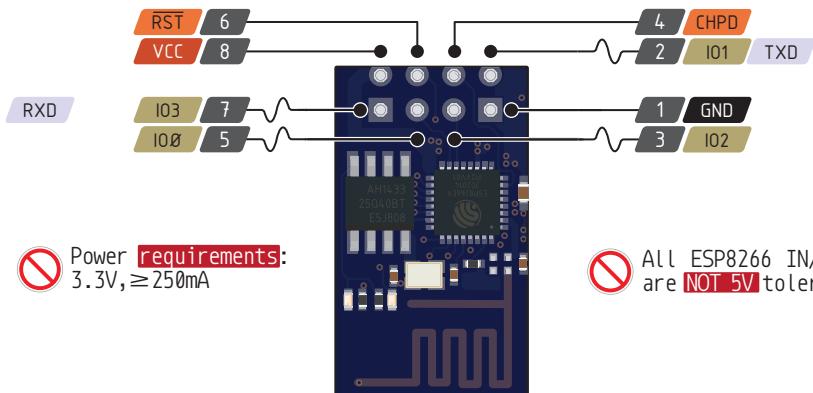
ESP8266
Simplified Pinout

ESP-12S

GND	9				8	VCC	

CS TXD2 IO15 10

IO2 11

IO0 12

SDA IO4 13

SCL IO5 14

RXD IO3 15

TXD IO1 16

8 VCC

7 IO13 RXD2 MOSI

6 IO12 MISO

5 IO14 CLK

4 IO16 WAKE

3 CHPD

2 ADC

1 RST

Power
GND
Physical PIN
Port PIN
Analog PIN
Serial PIN
Control PIN

⌇— PWM Pin

Absolute MAX per pin
12mA, 6mA recommended

IO15	IO0	IO2	Boot Mode
0V	0V	3.3V	UART Bootloader
0V	3.3V	3.3V	Boot Sketch (SPI Flash)

ESP-01

RST	6			4	CHPD	

VCC 8

RXD IO3 7

IO0 5

2 IO1 TXD

1 GND

3 IO2

🚫 Power **requirements**:
3.3V, ≥250mA

🚫 All ESP8266 IN/OUTs
are **NOT 5V** tolerant!

P5

0-1.es/P5

ESP8266
ESP-12S Minimal Setup

+5V

3.6V

4.3V

10kΩ

K A K A

1N4007

A   K

100µF
16V

16v
100µF

RESET

–   +

MODEL   ESP8266MOD
VENDOR   AI-THINKER
             ISM 2.4Ghz
             PA +25dBm
             80211b/g/n

RX   1

FLASH

TX   2

10kΩ

100Ω

K

A

3V3

Don't forget to connect all
the ground wires together!

FTDI
Pinout

RTS# RXD TXD VCC CTS# GND
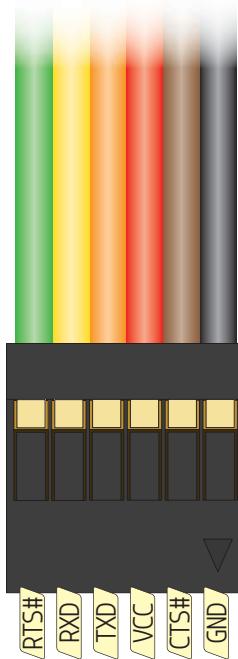
Check the I/O pin voltage before programming the microcontroller!
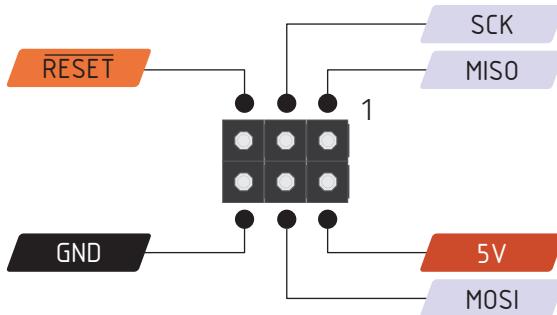
The FTDI cable is a USB to Serial (TTL level) converter which allows for a simple way to connect TTL interface devices to USB. Normally the I/O pins of FTDI cable are configured to operate at 5V. The FTDI cable uses the RTS signal for hardware reset when programming a microcontroller board.

P7

ICSP
Pinout

The ICSP header allows the microcontroller to receive the firmware or the bootloader. **ICSP** stands for In Circuit Serial Programming, it is a standard way to program AVR chips. ISCP uses six pins to program the microcontroller:

MISO: (Master In Slave Out): the slave line for sending data to the master.

MOSI: (Master Out Slave In): the master line for sending data to the peripherals.

SCK: (Serial Clock): the clock pulses that synchronize data transmission generated by the master.
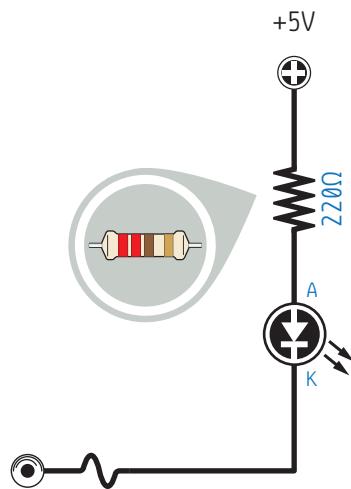
RESET: connected to the reset signal of the microcontroller.
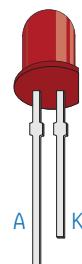
LED
Basic Connections
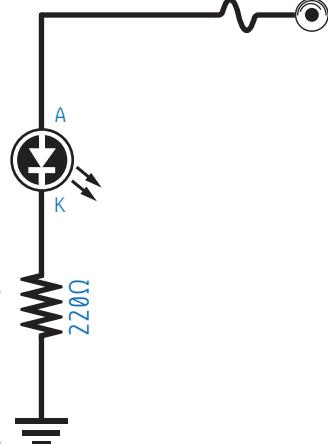
Reversing the polarity will not damage the LED

+5V

220Ω

A
K

A   K

LED turns on when pin is set to HIGH

LED turns on when pin is set to LOW

A
K

220Ω

Don't forget to connect all the ground wires together!

LEDs (ligth-emitting diodes) are components that are polarized and only allow current to flow in one direction. LEDs normally have two terminals: the anode (A) or positive side (the longer lead), and the cathode (K) or negative side (the shorter lead closest to the flat edge of the LED).

1

LED
Test Code

```
int LEDPin = 13;

void setup() {
    pinMode(LEDPin,OUTPUT);
}

void loop() {
    digitalWrite(LEDPin,HIGH);
    delay(1000);
    digitalWrite(LEDPin,LOW);
    delay(1000);
}
```

Assign variable *LEDPin* as pin 13

Initialize the pin as an OUTPUT

Turn the LED ON
Wait for 1 second
Turn the LED OFF
Wait for 1 second

Typical LED Current Limiting Resistor Values

Red — 220Ω

Green — 180Ω

Blue — 100Ω

Orange — 200Ω

White — 100Ω
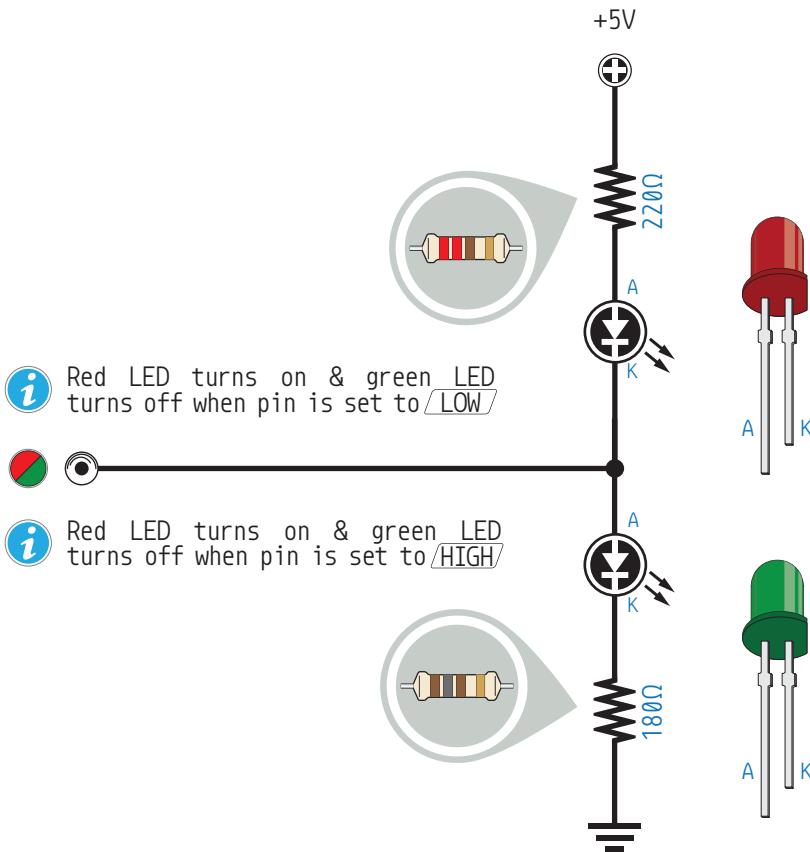
Limiting the current that flows through an LED is very important! For this purpose, a current limiting resistor is used in series with the LED. If you connect the LED directly (without a resistor in series) the microcontroller or the LED may suffer damage!

Alternating LEDs
Basic Connections

2

+5V

220Ω

180Ω

A
K

A
K

Red LED turns on & green LED turns off when pin is set to /LOW/

Red LED turns on & green LED turns off when pin is set to /HIGH/

A   K

A   K

3

Bi-Color LED
2-Lead LEDs

+5V

330Ω

330Ω

2   1

2   1

ℹ️ Red LED turns on when pin is set to /HIGH/
Green LED turns on when pin is set to /LOW/
Switch pin to /INPUT/ to turn off both LEDs

3-Lead LEDs

1   220Ω   A^G   K
                A^R

2   180Ω

A^G   A^R
    K

ℹ️ Red LED turns on when pin 1 is set to /HIGH/
Green LED turns on when pin 2 is set to /HIGH/
LED appears orange when both pins are set to /HIGH/

4

LED Cluster
Basic Connections

⚠ +12V

# of LEDs

1KΩ
1

820Ω
2

750Ω
3

680Ω
4

470Ω
5

390Ω
6

Rx

A

K

NPN
C
B
E

4.7kΩ

A   K

E ●●● C
B

2N2222

ⓘ LEDs turns on when
pin is set to HIGH

Don't forget to connect all
the ground wires together! ⚠

5
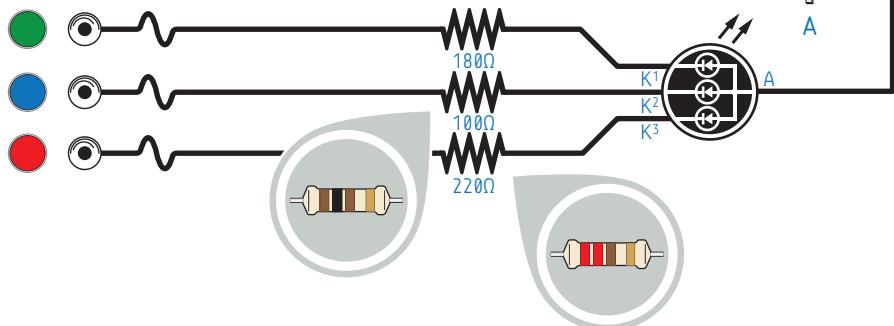
RGB LED
Common Cathode Configuration

i LED turns on when
pin is set to /HIGH/

180Ω

100Ω

220Ω

A¹
A²
A³
K

A¹
A²
A³

K
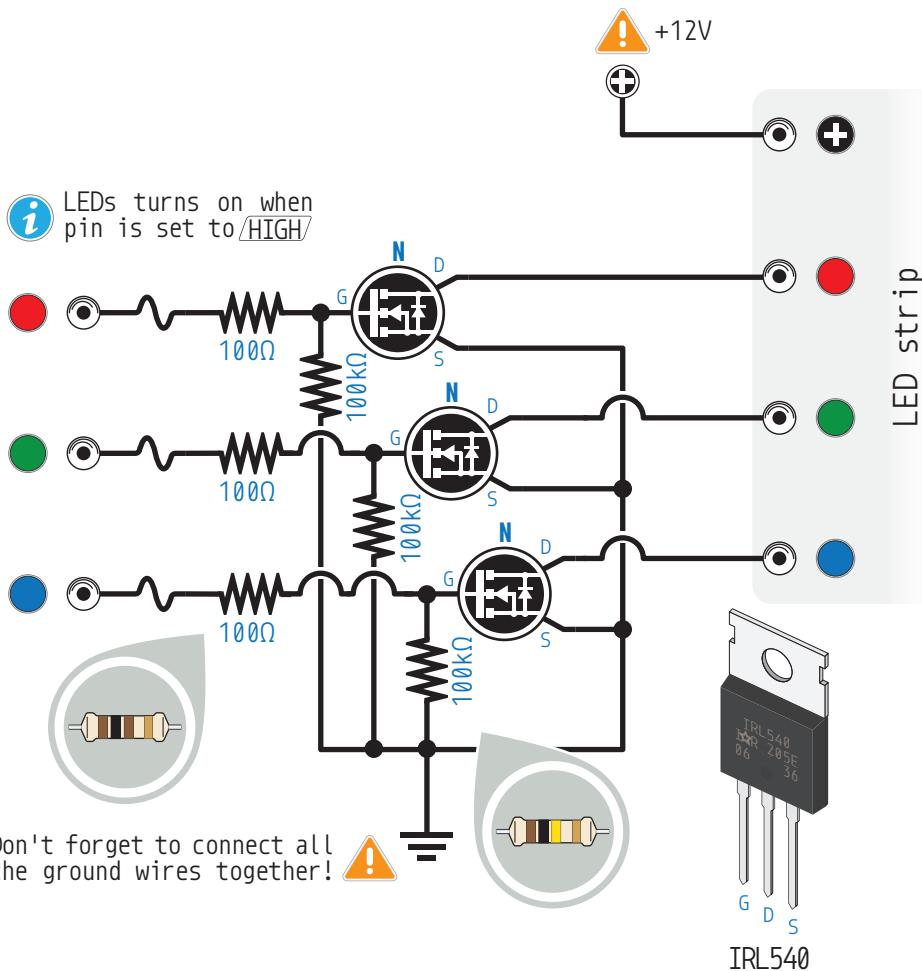
Common Anode Configuration

+5V

i LED turns on when
pin is set to /LOW/

180Ω

100Ω

220Ω

K¹
K²
K³
A

K¹
K²
K³

A

6

LED Strip
Basic Connections

⚠ +12V

ℹ LEDs turns on when pin is set to /HIGH/

100Ω

100kΩ

100Ω

100kΩ

100Ω

100kΩ

N D G S

N D G S

N D G S

Don't forget to connect all the ground wires together! ⚠

LED strip

IRL540

G D S
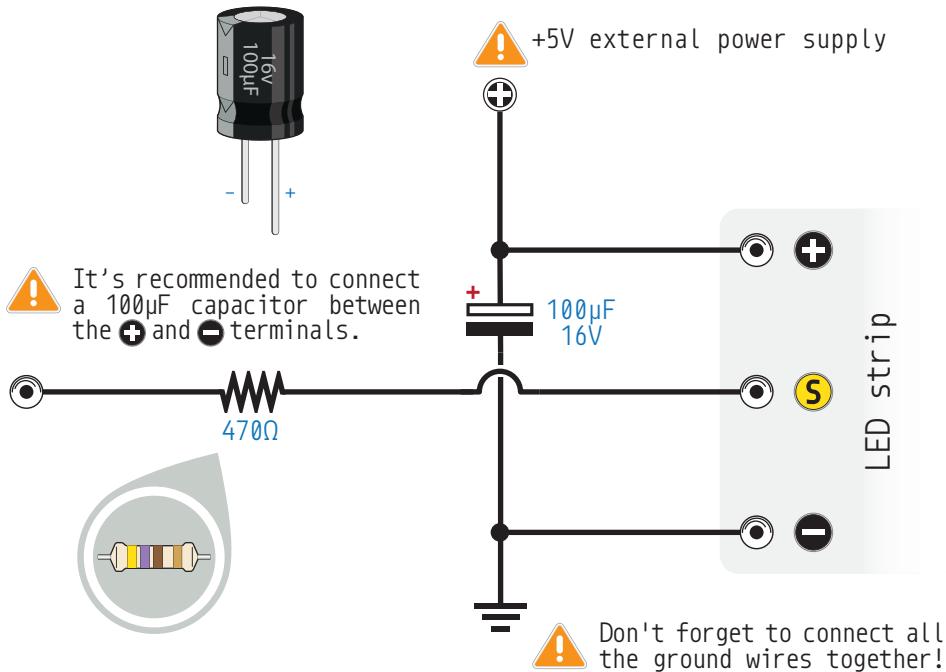
💡 A 1 meter long LED strip can draw nearly 1A when all LEDs are on full brightness. The I/O pins of most microcontroller boards can only supply up to 40mA each, so you will have to help it out with a driver circuit to boost the power. This circuit uses 3 PWM signals from the board and uses them to drive 3 MOSFETs.

7

Digitally-Addressable LEDs
Basic Connections

⚠ +5V external power supply

16V
100µF

– +

⚠ It's recommended to connect a 100µF capacitor between the ⊕ and ⊖ terminals.

+
100µF
16V

470Ω

LED strip

⊕

Ⓢ

⊖

⚠ Don't forget to connect all the ground wires together!

🚫 When connecting digitally-addressable LEDs to any LIVE power source or microcontroller, ALWAYS CONNECT GROUND (⊖) BEFORE ANYTHING ELSE. Conversely, disconnect ground last when detaching the LEDs.
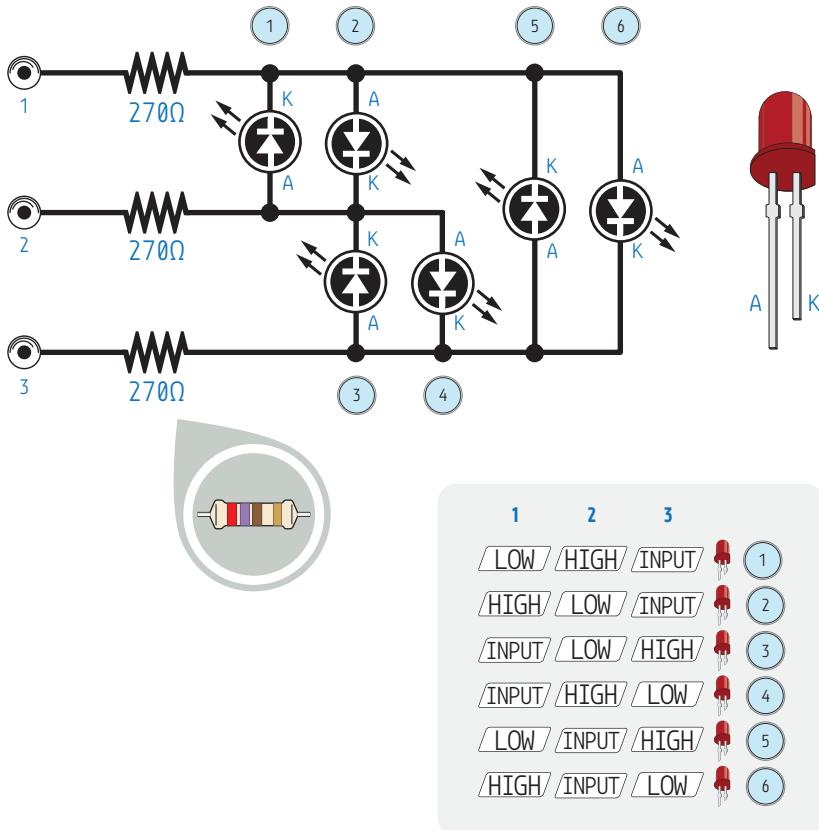
💡 This schematic is valid only for RGB color pixels and strips based on the WS2812, WS2811 and SK6812 LED drivers, which use a single-wire control protocol. Do not power the strip directly from the 5V pin of the microcontroller board! Each individual LED draws up to 60mA when set to white at maximum brightness.

8

Charlieplexing
Basic Connections

	1	2	3		
	LOW	HIGH	INPUT	🔴	1
	HIGH	LOW	INPUT	🔴	2
	INPUT	LOW	HIGH	🔴	3
	INPUT	HIGH	LOW	🔴	4
	LOW	INPUT	HIGH	🔴	5
	HIGH	INPUT	LOW	🔴	6
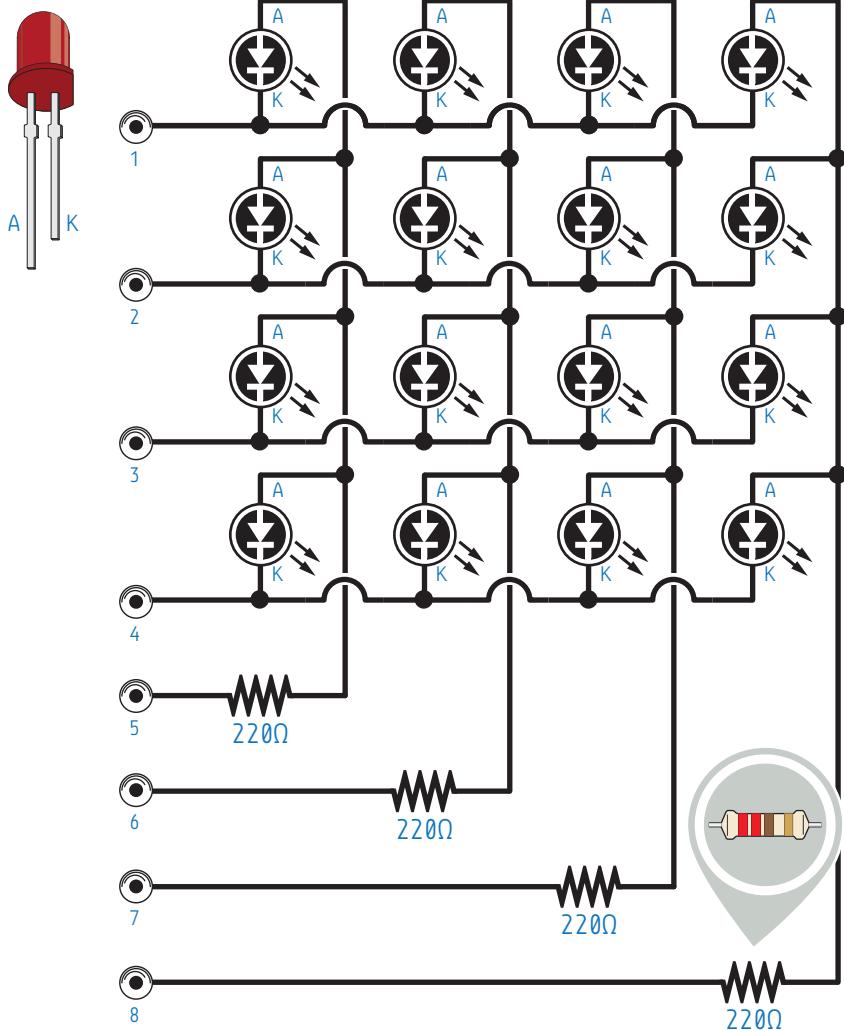
Charlieplexing is a technique for driving a multiplexed display in which relatively few I/O pins on a microcontroller are used to drive an array of LEDs. Not only does it take advantage of the two states that we normally change, HIGH and LOW, but it also uses a third state by changing between OUTPUT and INPUT modes.
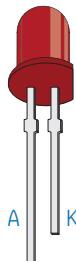
LED Matrix
Basic Connections

A K

1
2
3
4
5
220Ω
6
220Ω
7
220Ω
8
220Ω

10
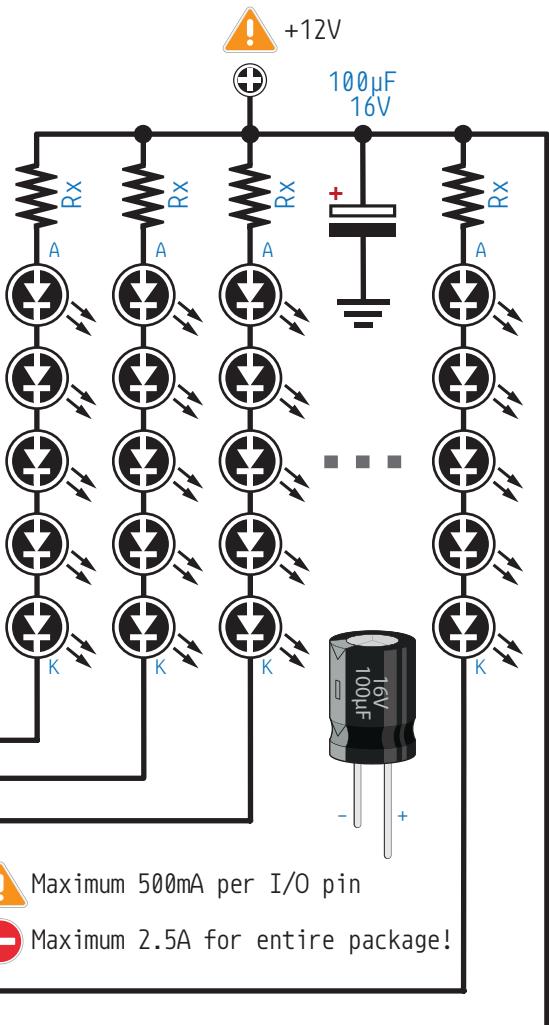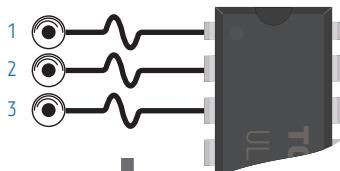
Multiple LED Clusters
Using the ULN2803 Darlington Transistor Array

⚠️ +12V

100µF
16V

# of LEDs

1 1KΩ

2 820Ω

3 750Ω

4 680Ω

5 470Ω

6 390Ω

ℹ️ LEDs turns on when pin is set to HIGH

1

2

3

8

16V
100µF

– +

⚠️ Maximum 500mA per I/O pin
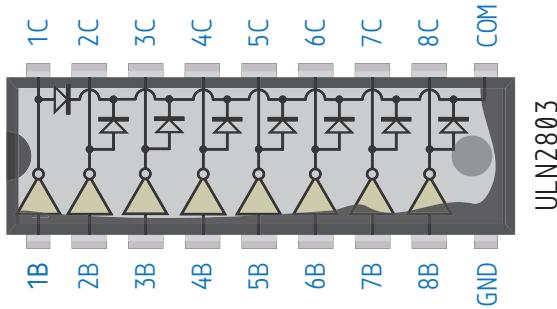
🚫 Maximum 2.5A for entire package!
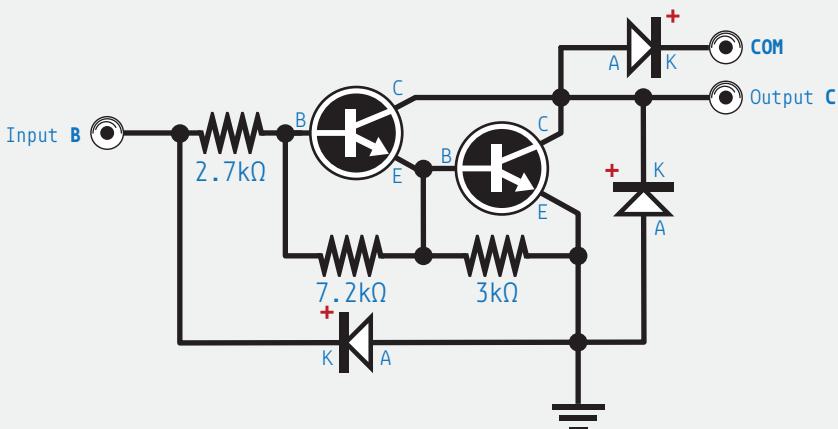
⚠️ Don't forget to connect all the ground wires together!

10

ULN2803
Pinout

1C 2C 3C 4C 5C 6C 7C 8C COM

ULN2803

1B 2B 3B 4B 5B 6B 7B 8B GND

Port Schematic

Input **B**

2.7kΩ

B
C
E

C
B
E

7.2kΩ

3kΩ

K A

+

A K

+

COM

Output **C**

K

A

+
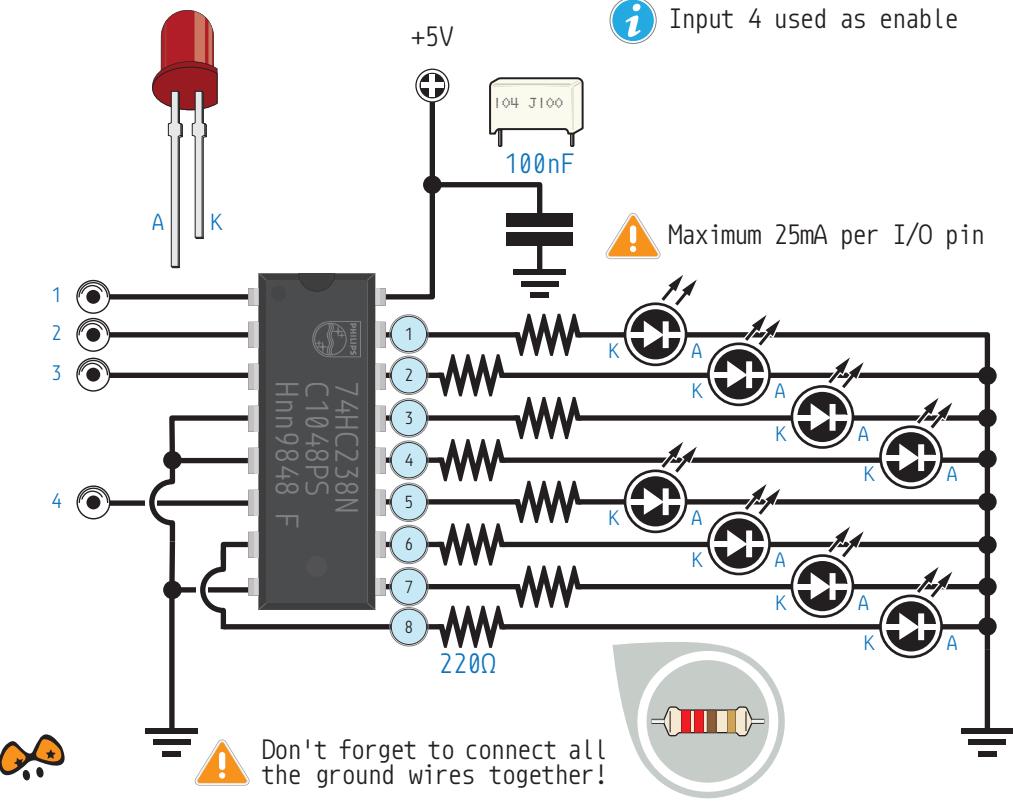
The ULN2803 is an octal Darlington transistor array that delivers up to 500mA of current for each pin and operates at up to 50V. You can drive motors, DC light bulbs, relays, solenoids, etc. The Darlington output pins can even be connected in parallel for higher current applications.

11
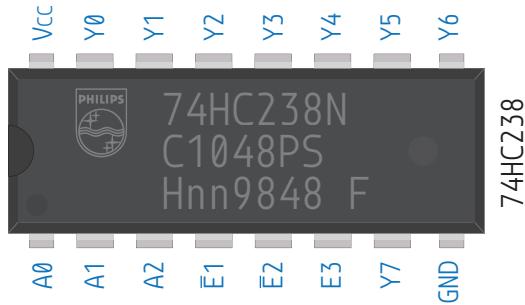
Decoder/Demultiplexer
Using the 74HC238 Decoder

1	**2**	**3**		
LOW	LOW	LOW		1
HIGH	LOW	LOW		2
LOW	HIGH	LOW		3
HIGH	HIGH	LOW		4

1	**2**	**3**		
LOW	LOW	HIGH		5
HIGH	LOW	HIGH		6
LOW	HIGH	HIGH		7
HIGH	HIGH	HIGH		8

i Input 4 used as enable

+5V

104 J100

100nF

A   K

⚠ Maximum 25mA per I/O pin

1
2
3

74HC238N
C1048PS
Hnn9848 F

4

220Ω

K A

⚠ Don't forget to connect all the ground wires together!

11

74HC238

Pinout

Vcc Y0 Y1 Y2 Y3 Y4 Y5 Y6

PHILIPS
74HC238N
C1048PS
Hnn9848 F

74HC238

A0 A1 A2 Ē1 Ē2 E3 Y7 GND

Connecting Multiple 74HC238

Slaves   Master Enable

You can drive
up to 64 LEDs!

The 74HC238 is a high speed CMOS 3-to-8 line decoder. It has three binary select
inputs (A0, A1, A2) which determine which one of the eight outputs (Y0-Y7) will
go high. This chip has three enable inputs (E1, E2, E3). If you leave E3 low,
no outputs can be set to high.

Shift Register

Using the 74HC595 Shift Register

⚠ Maximum 20mA per I/O pin

+5V

K K K K

A A A A

K K K K

A A A A

A   K

220Ω

104 J100

100nF

55ALS9KE4
SN74HC595N

DATA 1

LATCH 2

CLK 3

SDO 4

Don't forget to connect all
the ground wires together! ⚠

SDO outputs the over-
flown bit to be shifted ℹ

74HC595

Pinout

Vcc QA SER OE RCLK SRCLK SRCLR QH'

55ALS9K E4
SN74HC595N

74HC595

QB QC QD QE QF QG QH GND

Connecting Multiple 74HC595

Data flow

Data OUT

Clock   Data IN   Latch
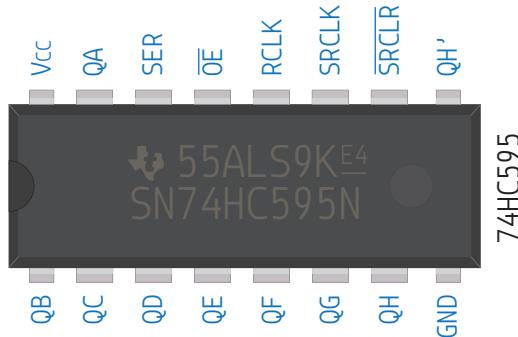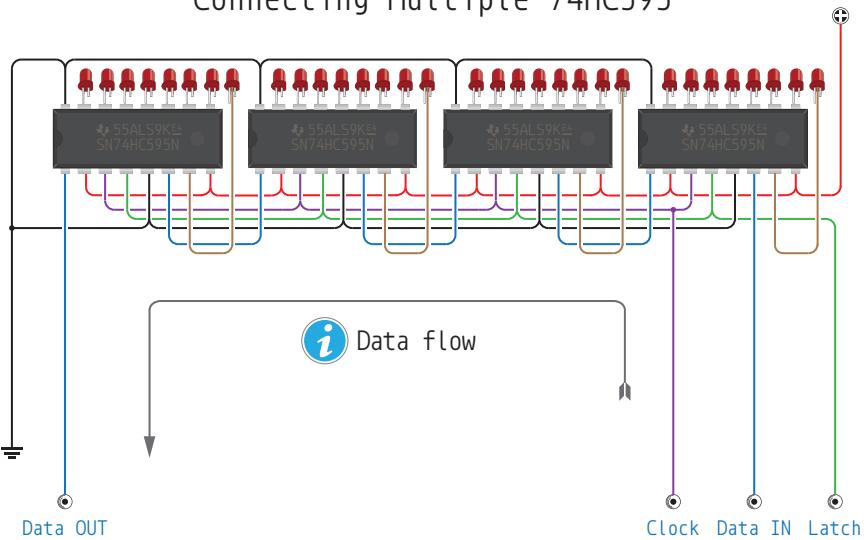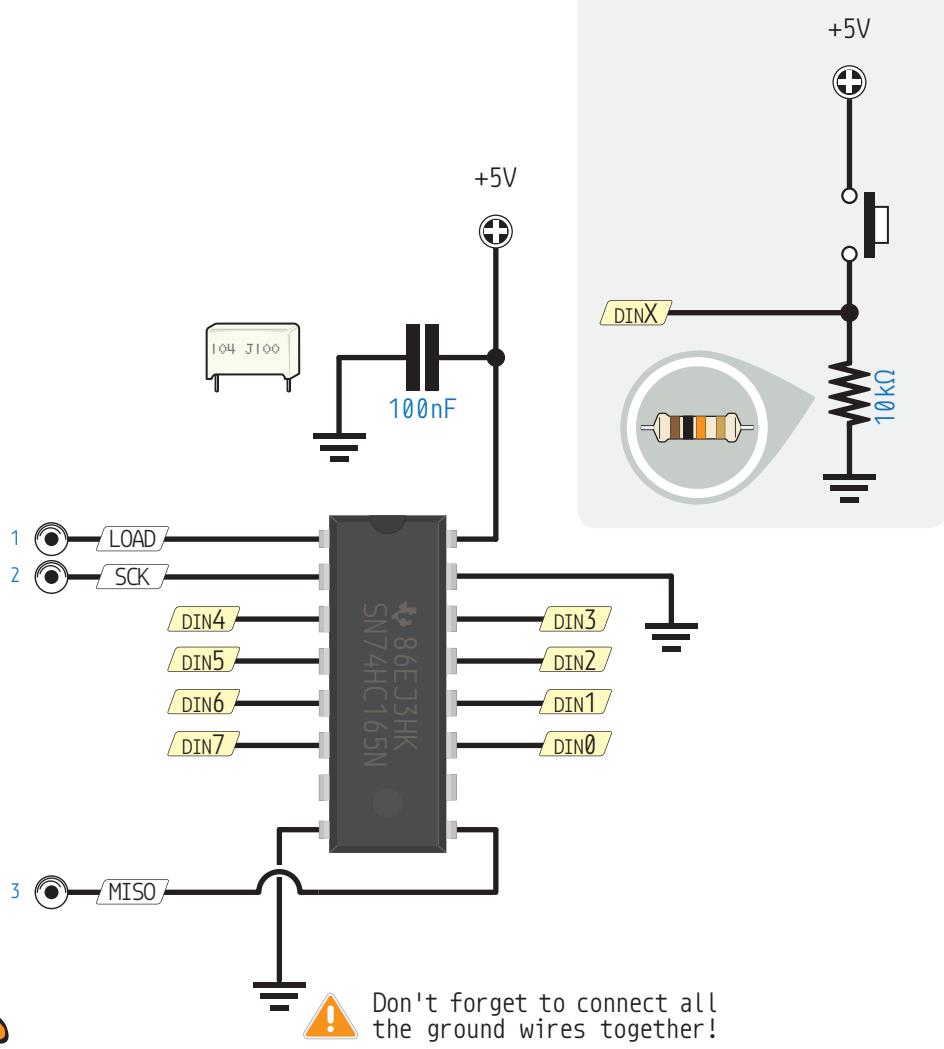
The 74HC595 is an 8-bit shift register. It takes 8 bits from the serial input and outputs them to 8 pins. You can daisy chain them together so it's really easy to control a big number of LEDs or power transistors from only 3 digital microcontroller pins.

13

Input Shift Register Via SPI
Using the 74HC165 Shift Register
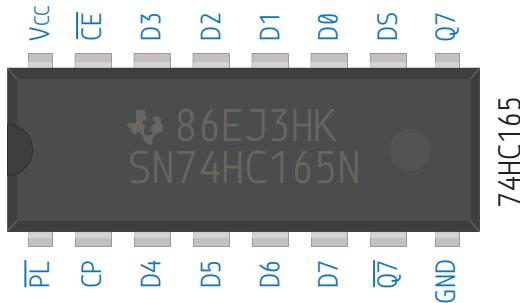
+5V

+5V

DINX

10kΩ

104 J100

100nF

1 LOAD
2 SCK

DIN4   DIN3
DIN5   DIN2
DIN6   DIN1
DIN7   DIN0

SN74HC165N
86EJ3HK

3 MISO

Don't forget to connect all
the ground wires together!

13

74HC165

Pinout

Vcc CE D3 D2 D1 D0 DS Q7

86EJ3HK
SN74HC165N

74HC165

PL CP D4 D5 D6 D7 Q7 GND
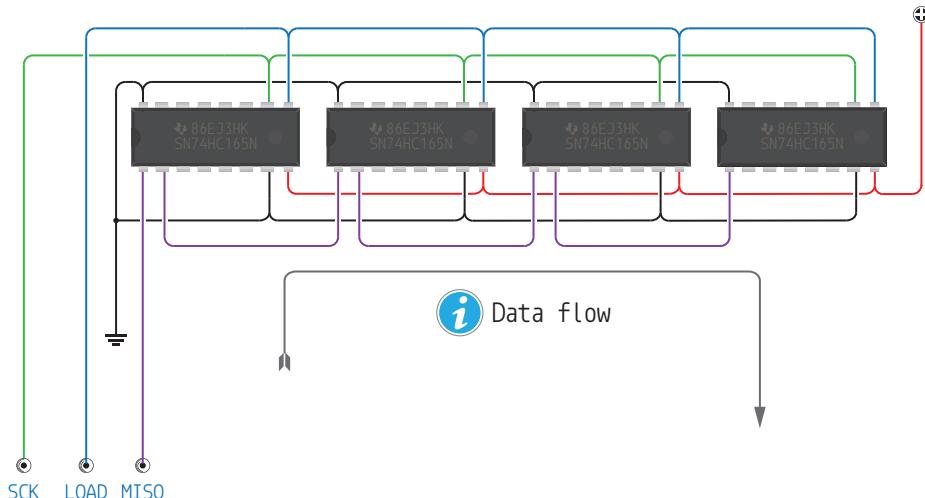
Connecting Multiple 74HC165

i Data flow

SCK LOAD MISO
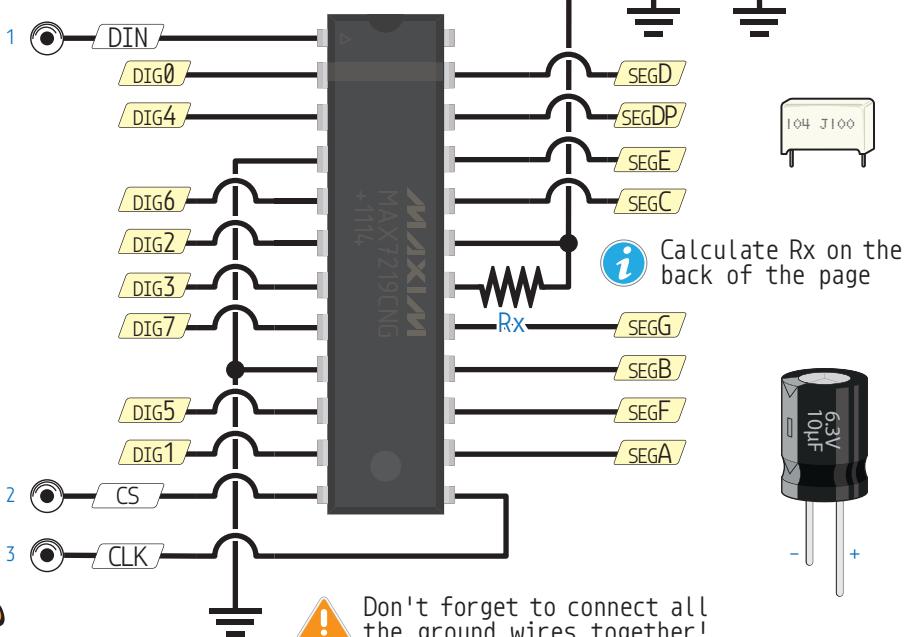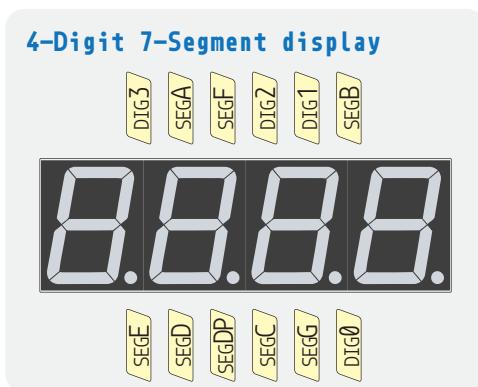
The 74HC165 is an 8-bit parallel-load or serial-in shift registers with comple-
mentary serial outputs available from the last stage. You can daisy chain them
together so it's really easy to control a big number of LEDs or power transistors
from only 3 digital microcontroller pins.

14
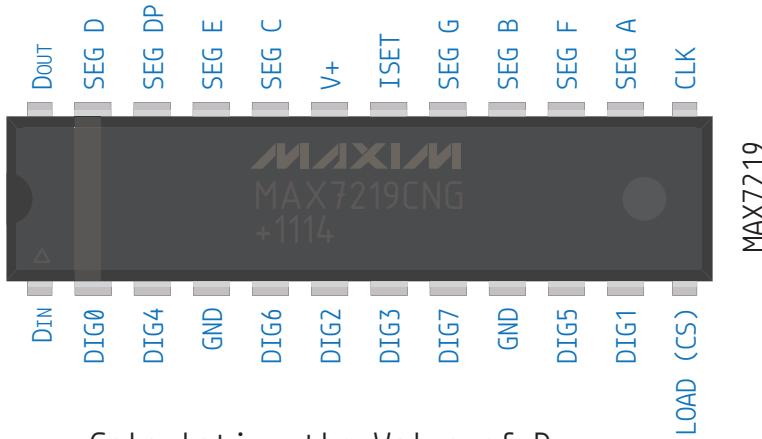
MAX7219 7-Seg. Display Driver
Connecting a 4-Digit 7-Segment Display

4-Digit 7-Segment display

DIG3 SEGA SEGF DIG2 DIG1 SEGB

SEGE SEGD SEGDP SEGC SEGG DIG0

A
F
B
G
E
C
DP
D

+5V

10µF
6.3V
100nF

+

1 DIN

DIG0 — SEGD
DIG4 — SEGDP
SEGE
DIG6 SEGC
DIG2
DIG3
DIG7 Rx SEGG
SEGB
DIG5 SEGF
DIG1 SEGA

MAXIM
MAX7219CNG
+1114

2 CS
3 CLK

104 J100

Calculate Rx on the
back of the page

6.3V
10µF

−   +

Don't forget to connect all
the ground wires together!

MAX7219

Pinout

Pins (top, left to right): D OUT, SEG D, SEG DP, SEG E, SEG C, V+, ISET, SEG G, SEG B, SEG F, SEG A, CLK

MAX7219

Pins (bottom, left to right): D IN, DIG0, DIG4, GND, DIG6, DIG2, DIG3, DIG7, GND, DIG5, DIG1, LOAD (CS)

Calculating the Value of Rx

The MAX7219 is a constant-current LED driver. Resistor Rx is used to set the current for the LEDs. You will need to know the voltage and forward current for your LED display or matrix and match the value on the table below. E.g., if you have a 2V, 20mA LED, your resistor value must be 28kΩ.

I_{SEG}(mA)	V_{LED}(V)				
	1.5	2.0	2.5	3.0	3.5
40	12.2	11.8	11.0	10.6	9.69
30	17.8	17.1	15.8	15.0	14.0
20	29.8	28.0	25.9	24.5	22.6
10	66.7	63.7	59.3	55.4	51.2

Values in kΩ

The MAX7219 is a powerful serial input/output common-cathode display driver that interfaces microcontrollers with 7-segment numeric LED displays of up to 8 digits. It has a built-in BCD decoder and brightness control. You could also use it to drive individual LEDs, Bar-graphs LEDs, or 8×8 LED matrix displays.

15
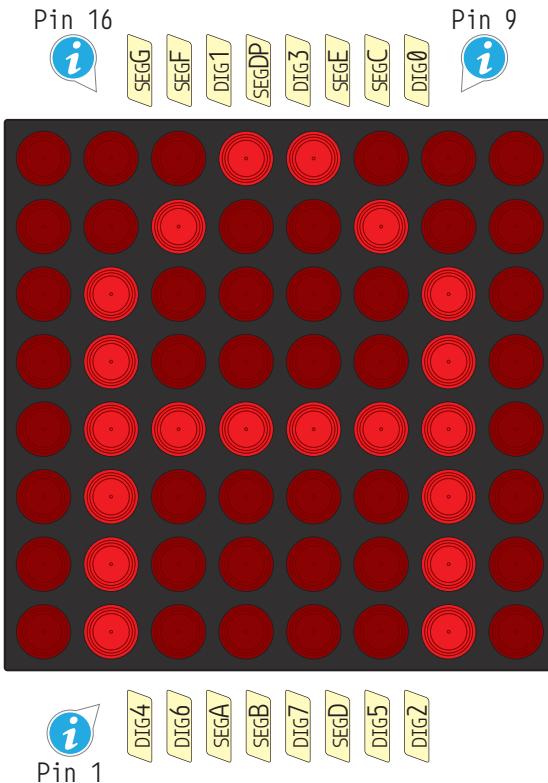
LEDM88G 8x8 LED Matrix
Using the MAX7219 LED Display Driver

⚠️ Use a common-cathode LED matrix

Pin 16 ℹ️   SEGG SEGF DIG1 SEGDP DIG3 SEGE SEGC DIG0   ℹ️ Pin 9

ℹ️ Pin 1   DIG4 DIG6 SEGA SEGB DIG7 SEGD DIG5 DIG2
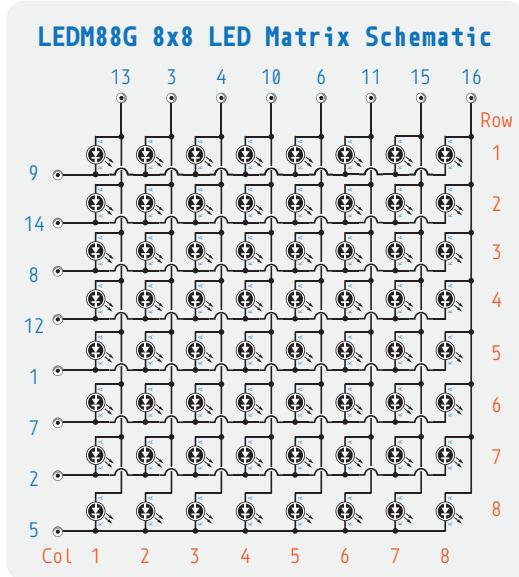
ℹ️ Pin 1 is the first pin starting from the left if you orient the device so that the part number is facing towards you

15

LEDM88G 8x8 LED Matrix Schematic
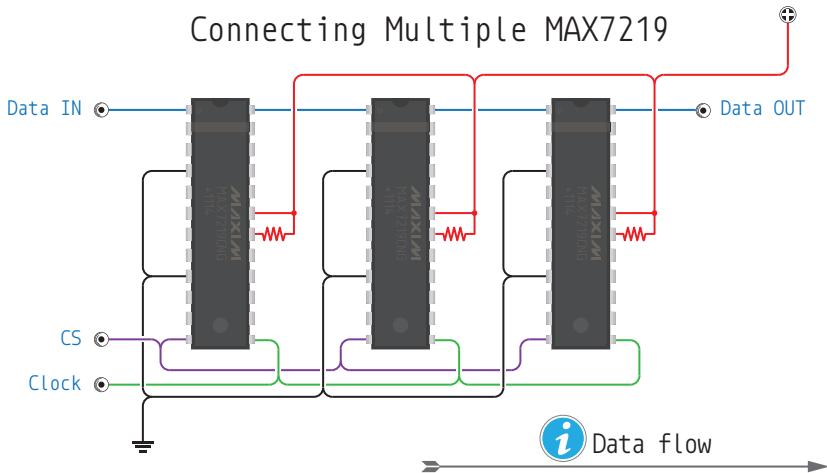
Connecting Multiple MAX7219

Data IN

Data OUT

CS

Clock

Data flow
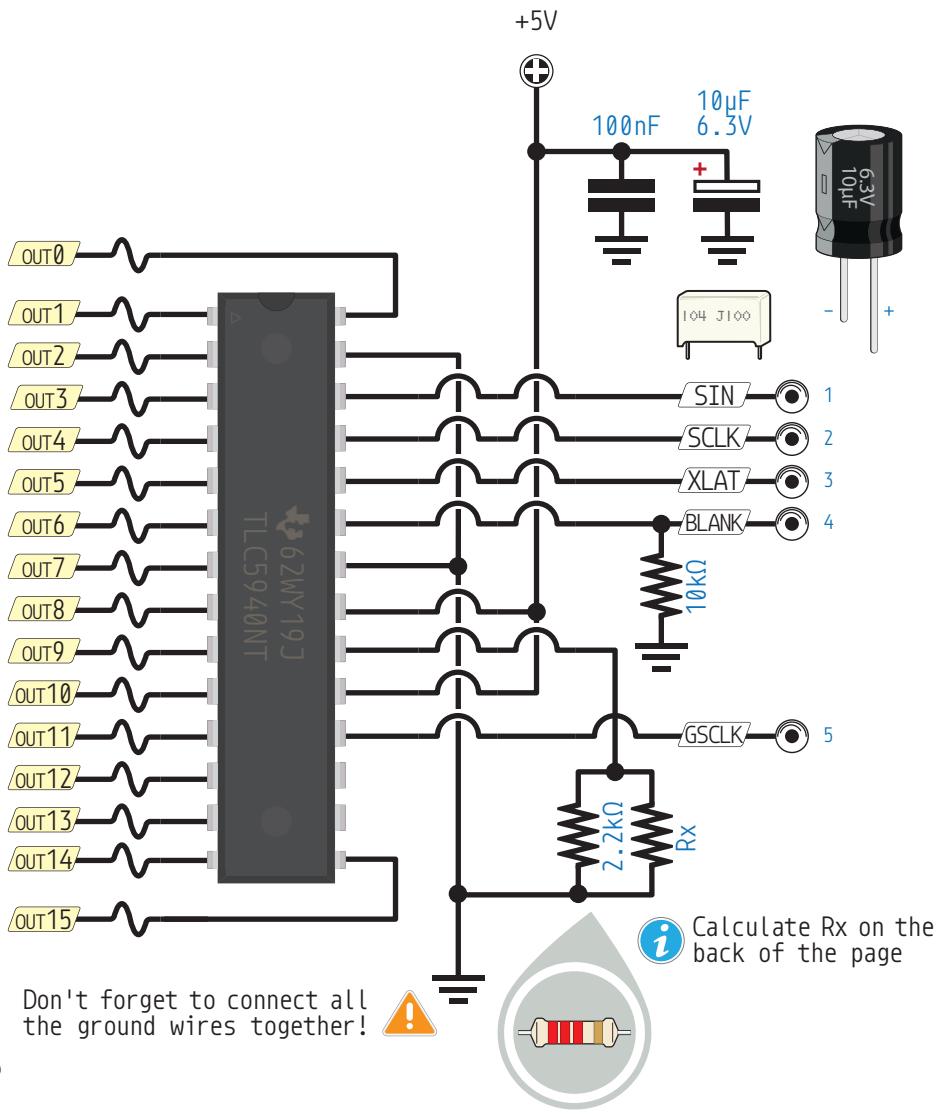
Using one MAX7219 you can drive up to 64 LEDs using only 4 wires to interface with a microcontroller. This powerful LED driver is designed to be daisy-chained so you can connect multiple 64-pixel displays together (like those scrolling signs you see in shop windows).

16

TLC5940 LED Driver
Basic Connections

+5V

10µF
6.3V

100nF

104 J100

OUT0
OUT1
OUT2
OUT3
OUT4
OUT5
OUT6
OUT7
OUT8
OUT9
OUT10
OUT11
OUT12
OUT13
OUT14
OUT15

62WY19J
TLC5940NT

SIN   1
SCLK   2
XLAT   3
BLANK   4

10kΩ

GSCLK   5

2.2kΩ   Rx

Calculate Rx on the
back of the page

Don't forget to connect all
the ground wires together!

TLC5940

Pinout

O0 VPRG SIN SCLK XLAT BLANK GND Vcc IREF DCPRG GSCLK SOUT XERR O15

62WY19J
TLC5940NT

TLC5940

O1 O2 O3 O4 O5 O6 O7 O8 O9 O10 O11 O12 O13 O14
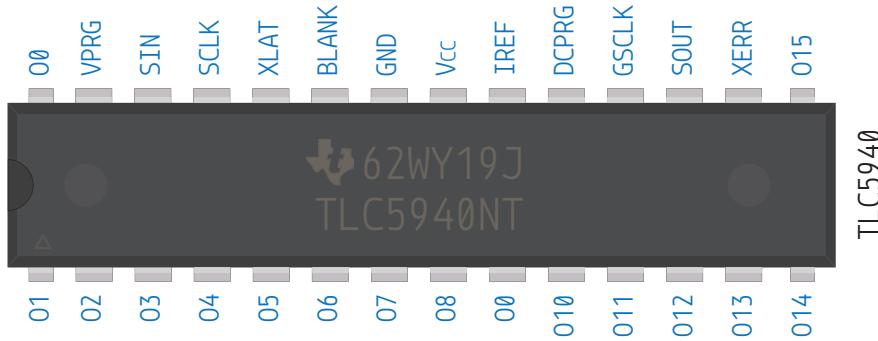
Calculating the value of Rx

The TLC5940 is a constant-current LED driver. The value of Rx has to be calculated according to the output current that is best suited for your application. If you want to connect components that draw 18mA of current use Ohm's law to calculate the resistor value as shown below.

$$Rx = V / I$$
$$Rx = 39.06V / 0.018A$$
$$Rx = 2.170 \approx \textbf{2.2k}\Omega$$

ⓘ The number 39.06 comes from the on-chip 1.24V voltage reference multiplied by a gain of 31.5, therefore 1.24 × 31.5 = 39.06V
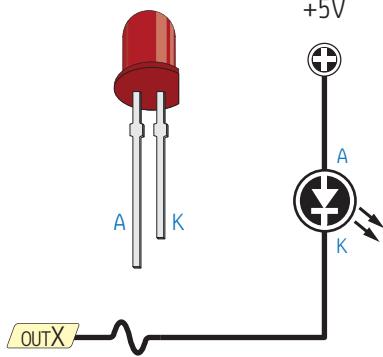
💡 The TLC5940 is a 16-channel, constant-current sink LED driver. Each channel has an individually adjustable 4096-step grayscale PWM brightness control, 6 bit current limit control (0-63), and a daisy chainable serial interface. Use this schematic to increase the number of PWM pins available to your microcontroller.

16

TLC5940 LED Driver
Connecting LEDs

+5V

A

A   K

K

OUTX
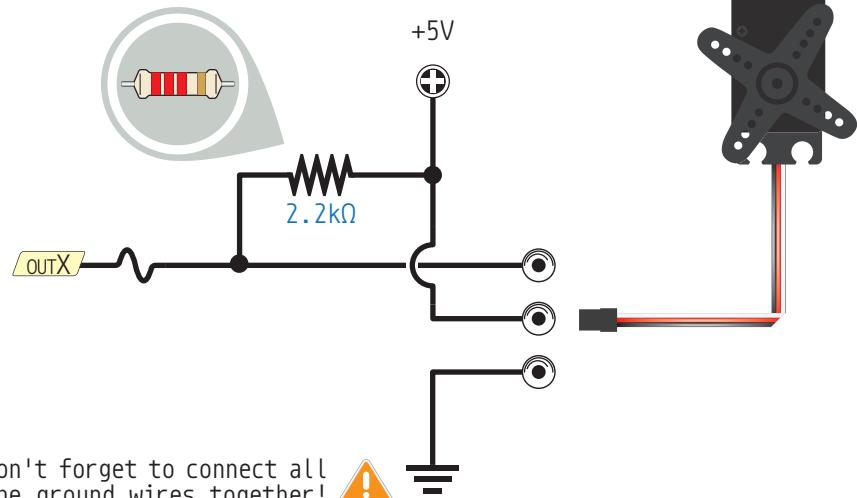
You can connect outputs in parallel to sink different current levels

Paralleleds outputs	LED current range (mA)	Number of LEDs per chip
1	0-80	16
2	0-160	8
3	0-240	5
6	0-480	2
8	0-640	2
16	0-1280	1

Connecting Servos

+5V

OUTX

2.2kΩ
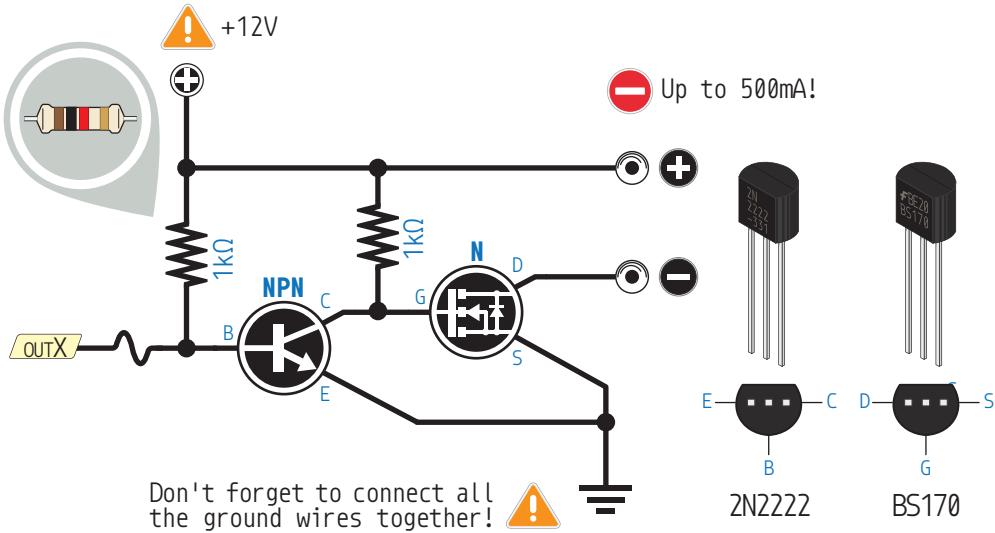
Don't forget to connect all the ground wires together!

16
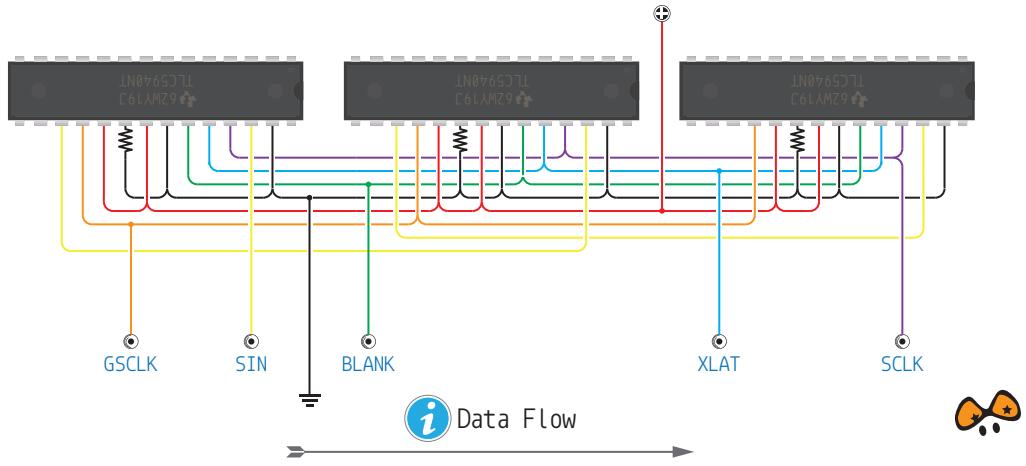
TLC5940 LED Driver
Connecting High-Power LEDs

+12V

Up to 500mA!

1kΩ

1kΩ

NPN

C

B

E

outX

N

D

G

S

Don't forget to connect all
the ground wires together!

E ●●● C

D ●●● S

B

G

2N2222

BS170
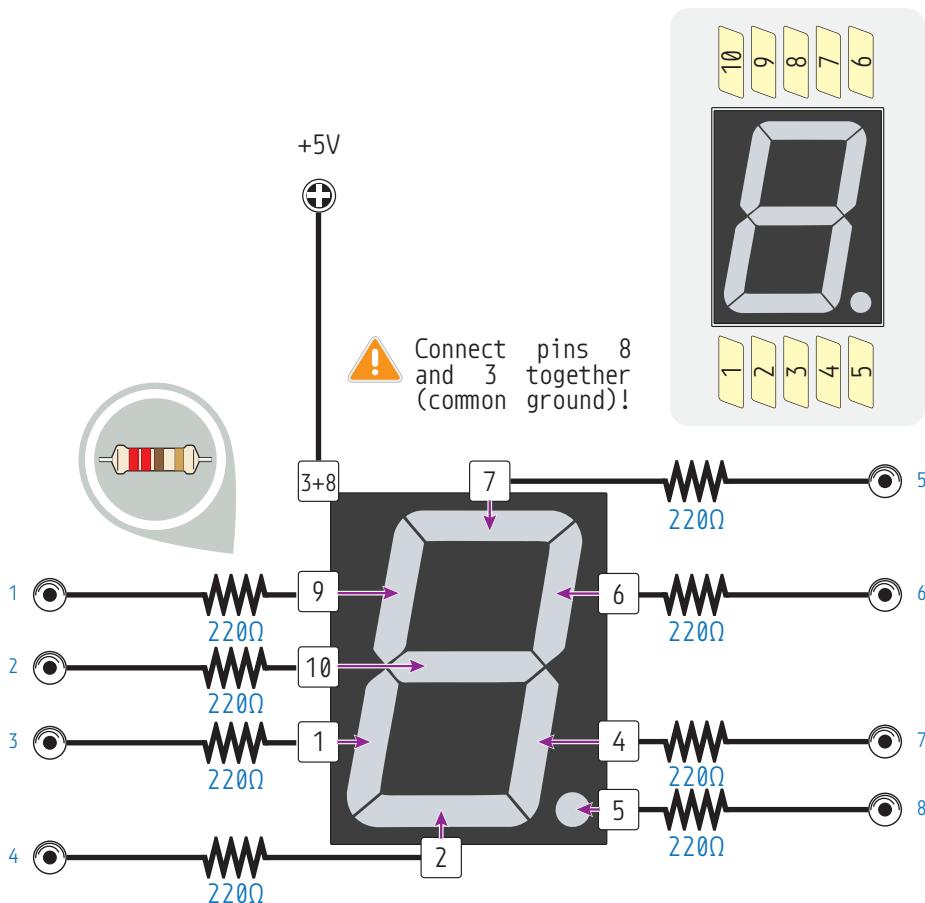
Connecting Multiple TLC5940

TLC5940NT

TLC5940NT

TLC5940NT

GSCLK

SIN

BLANK

XLAT

SCLK

Data Flow

17

7-Segment Display
Common-Cathode Connections

+5V

⚠ Connect pins 8 and 3 together (common ground)!

3+8

7   220Ω   5

1   220Ω   9   6   220Ω   6

2   220Ω   10

3   220Ω   1   4   220Ω   7

5   220Ω   8

4   220Ω   2
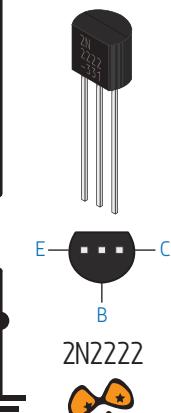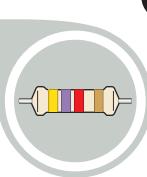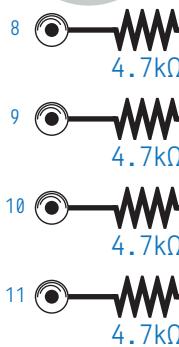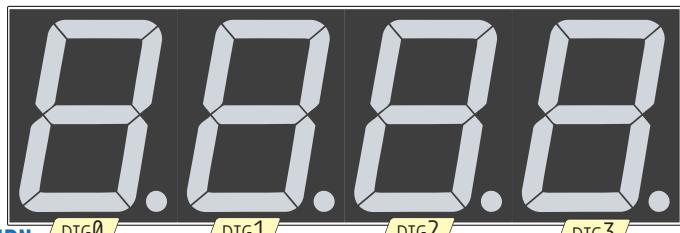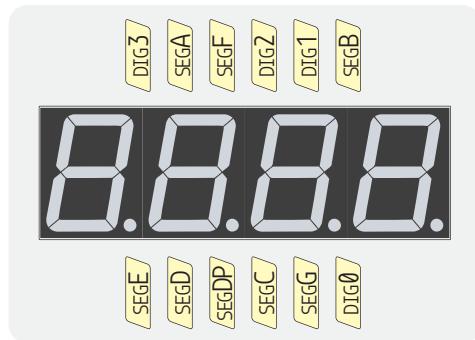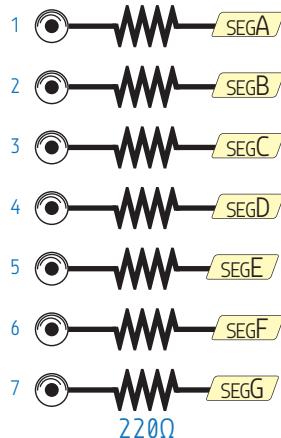
💡 A 7-Segment LED display is an electronic device housing 8 individual LEDs so you should use current-limiting resistors in series with the microcontroller pins. The segments can be combined to produce simplified representations of the arabic numerals or symbols.

18

4-Digit 7-Segment Display
Basic Connections

1 —WWW— SEGA
2 —WWW— SEGB
3 —WWW— SEGC
4 —WWW— SEGD
5 —WWW— SEGE
6 —WWW— SEGF
7 —WWW— SEGG

220Ω

DIG3 SEGA SEGF DIG2 DIG1 SEGB

SEGE SEGD SEGDP SEGC SEGG DIG0

NPN

DIG0   DIG1   DIG2   DIG3

8 —WWW— B NPN C
4.7kΩ   E

9 —WWW— B NPN C
4.7kΩ   E

10 —WWW— B NPN C
4.7kΩ   E

11 —WWW— B NPN C
4.7kΩ   E

2N2222

E —•••— C
B

Don't forget to connect all
the ground wires together! ⚠

19
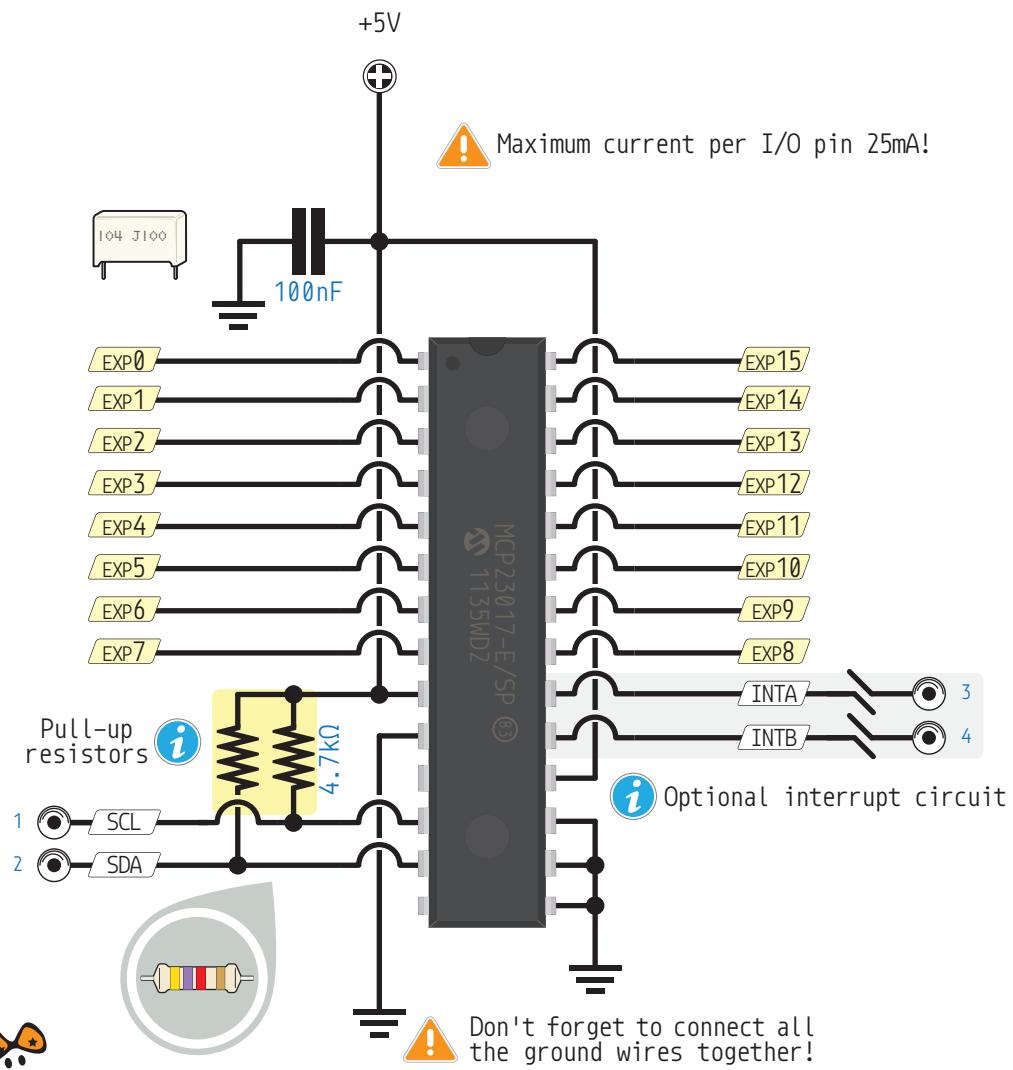
I/O Expander
Using the MCP23017 I/O Expander

+5V

⚠ Maximum current per I/O pin 25mA!

104 J100

100nF

EXP0
EXP1
EXP2
EXP3
EXP4
EXP5
EXP6
EXP7

MCP23017-E/SP
1135WD2

EXP15
EXP14
EXP13
EXP12
EXP11
EXP10
EXP9
EXP8

INTA   3
INTB   4

Pull-up
resistors ⓘ

4.7kΩ

ⓘ Optional interrupt circuit

1 SCL
2 SDA

⚠ Don't forget to connect all
the ground wires together!

MCP23017

Pinout

GPA7 GPA6 GPA5 GPA4 GPA3 GPA2 GPA1 GPA0 INTA INTB RESET A2 A1 A0

MCP23017–E/SP ⑧③
1135WD2

MCP23017

GPB0 GPB1 GPB2 GPB3 GPB4 GPB5 GPB6 GPB7 VDD VSS NC SCL SDA NC

Connecting an LED

EXP X ——— 220Ω ——— A ▷|◁ K ——— ⏚

A   K

Connecting a Pushbutton

+5V

10kΩ

EXP X

20
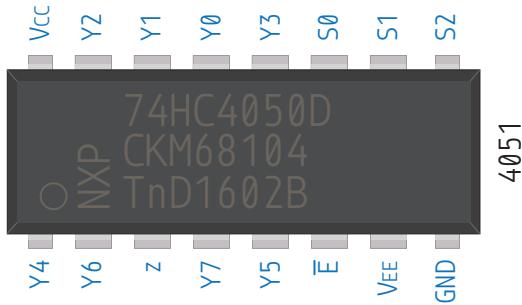
Analog Mux/Demux
Using the 4051 Mux/Demux

AINX

A

K

220Ω

A   K

+5V

100nF

104 J100

S0	S1	S2	Input
			AIN0
■			AIN1
	■		AIN2
■	■		AIN3
		■	AIN4
■		■	AIN5
	■	■	AIN6
■	■	■	AIN7

■ HIGH □ LOW

AIN4

AIN6

AIN2

1 AOUT

AIN1

AIN7

AIN0

AIN5

AIN3

NXP
74HC4051D
LH36E207
UnD1417F

S0 2

S1 3

S2 4

+5V

AINX

⚠ Maximum 20mA per I/O pin

4051
Pinout

Vcc Y2 Y1 Y0 Y3 S0 S1 S2

74HC4050D
NXP CKM68104
TnD1602B

4051

Y4 Y6 z Y7 Y5 Ē VEE GND
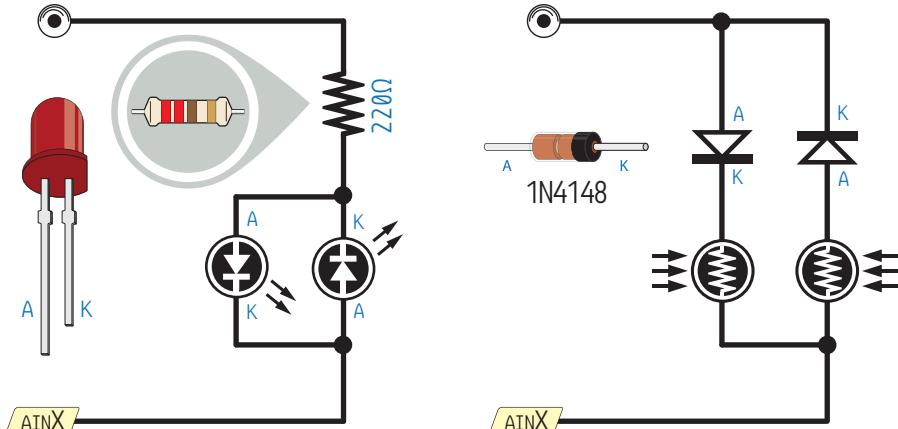
Doubling the Number of Ports
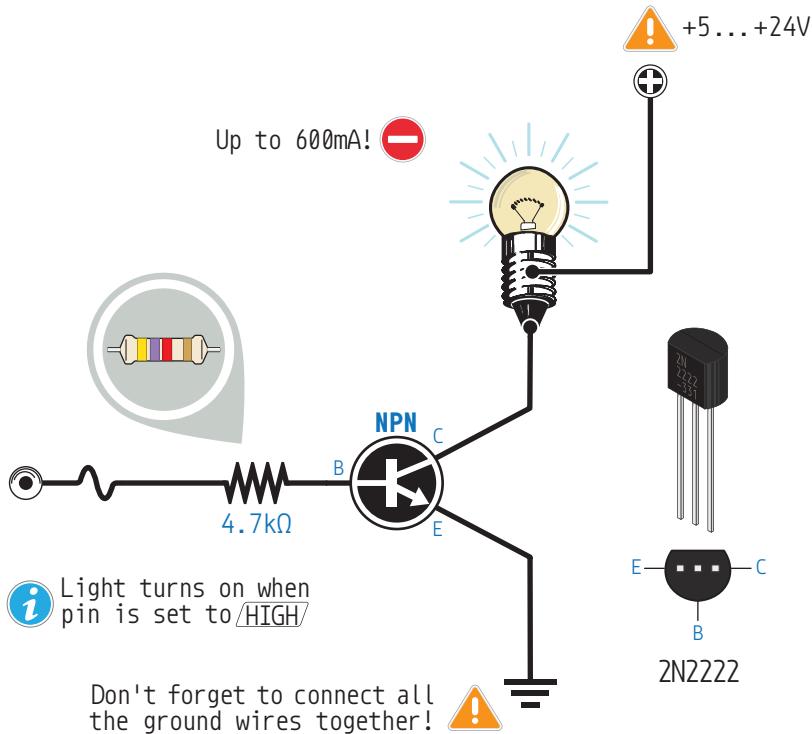
220Ω

A K

A K

A K

K A

AINX

1N4148

A K

A K

A K

AINX

21

DC Light Bulb
Low-Power Load

+5...+24V

Up to 600mA!

NPN
C
B
E

4.7kΩ

2N2222

E — C
B

i Light turns on when pin is set to HIGH

Don't forget to connect all the ground wires together!

Microcontrollers can only output a very small amount of current from their output pins. These pins are meant to send control signals, not to act as power supplies. The most common way to control a direct current device from a micro-controller is to use a transistor.

22

DC Light Bulb
High−Power Load

⚠ Don't forget to attach a heat sink to the MOSFET if are connecting a high−power load!

⚠ +5...+24V

Up to 28A! ⛔

ⓘ Light turns on when pin is set to /HIGH/

N

G
D
S

100Ω

100kΩ

IRL540

IRL540
06 205E
06   36

G D S

⚠ Don't forget to connect all the ground wires together!

💡 The 2N2222 transistor is rated at 800mA maximum, but you should leave a good safety margin. Many electronics projects designed for switching high−current DC loads use MOSFETs. If your lamp is greater than 2W, you need a MOSFET. The IRL540 can deliver its specified 28A continuous current at 5V.

23
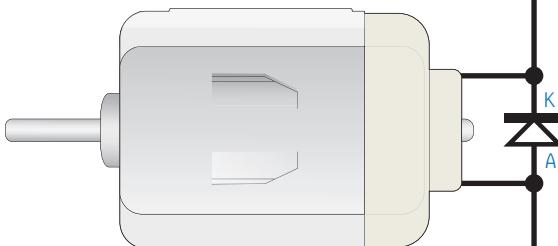
DC Motor
Basic Connections

⚠ +5...+48V

If you forget to connect the diode you could destroy the MOSFET! ⛔

⛔ Up to 28A!

K
A

A ▬ K
1N4007

ℹ Motor turns on when pin is set to /HIGH/

100Ω

G
N D
S

100kΩ

IRF540N
IOR 836P
ZE 31

G D S
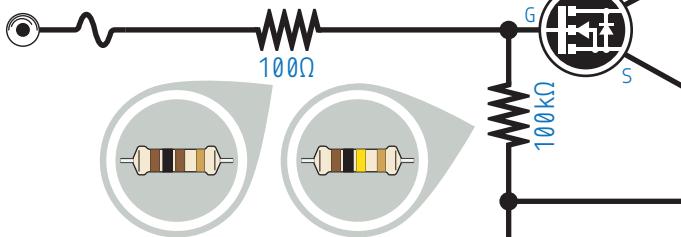
IRF540

⚠ Don't forget to attach a heat sink to the MOSFET if are connecting a high-power load!

⚠ Don't forget to connect all the ground wires together!
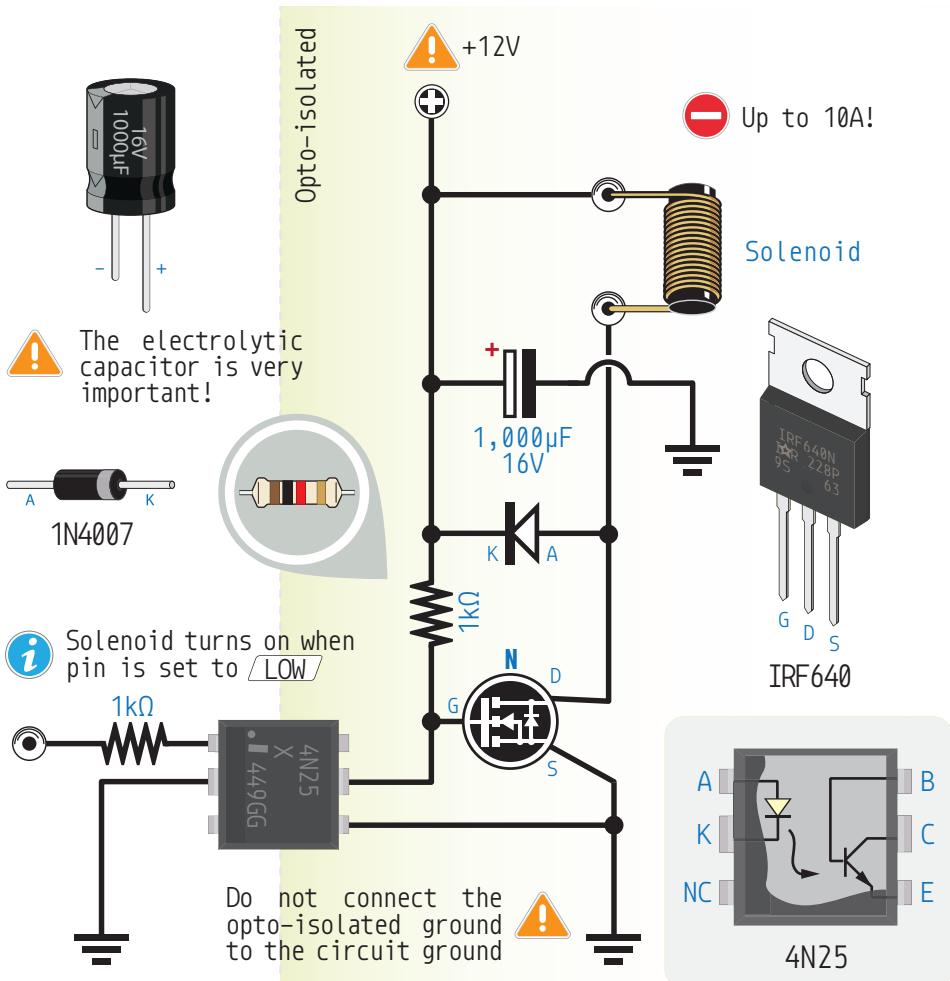
💡 DC motors can create harmful voltage spikes due to their inductive nature. In this schematic the capacitor used for filtering the noise caused by the motor and the diode is used to protect the power supply from reverse voltage caused by the motor acting like an inductor.

24
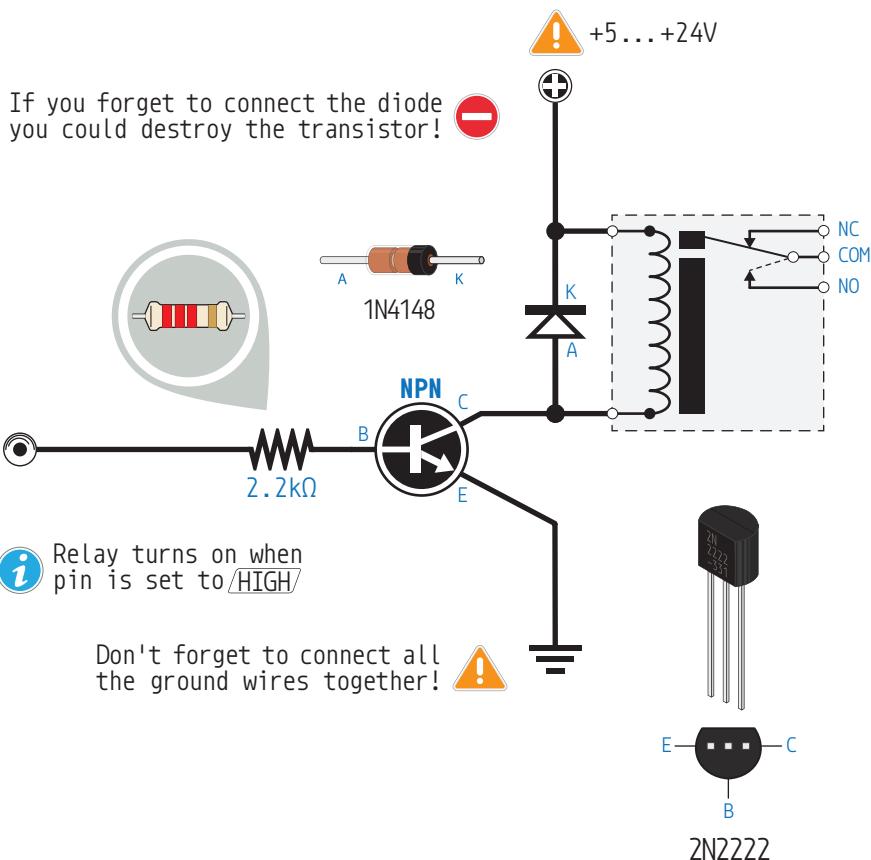
Solenoid
Basic Connections

Opto-isolated

⚠ +12V

⛔ Up to 10A!

16V
1000µF

− +

⚠ The electrolytic capacitor is very important!

Solenoid

1N4007
A   K

+
1,000µF
16V

K ◁ A

1kΩ

IRF640N
IR 228P
9S   63

G D S

IRF640

ⓘ Solenoid turns on when pin is set to LOW

N

G   D

S

1kΩ

4N25
X
449GG

A ▷ B

K   C

NC   E

4N25

Do not connect the opto-isolated ground to the circuit ground ⚠

It's very important to use a large electrolytic capacitor in this circuit. The capacitor is used for supplying the current required by solenoid when the circuit is activated.

25

Relay
Basic Connections

⚠ +5...+24V

If you forget to connect the diode 🚫
you could destroy the transistor!

A ▬ K
1N4148

K
A

2.2kΩ

NPN C
B
E

NC
COM
NO

ℹ Relay turns on when
pin is set to HIGH

Don't forget to connect all ⚠
the ground wires together!

2N
2222

E ▬ C
B
2N2222

💡 Relays have two types of contacts: NO and NC. NO stands for "Normally Open",
whereas NC stands for "Normally Closed". When the relay is turned off, NO
contacts are open and NC contacts are closed. On the other hand, when the relay
is turned on, NO contacts are closed and NC contacts are open.

25
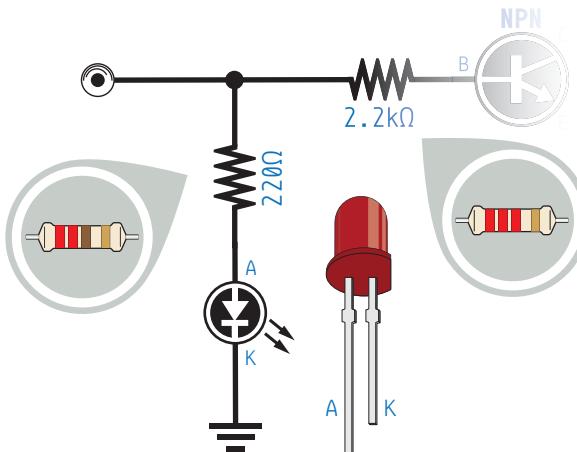
Relay
Test Code

```
int relayPin = 9;                          Assign variable relayPin as pin 9

void setup() {
        pinMode(relayPin,OUTPUT);          Initialize the pin as an OUTPUT
}

void loop() {
        digitalWrite(relayPin,HIGH);       Turn the relay ON
        delay(3000);                       Wait for 3 seconds
        digitalWrite(relayPin,LOW);        Turn the relay OFF
        delay(3000);                       Wait for 3 seconds
}
```

Status LED for the Relay
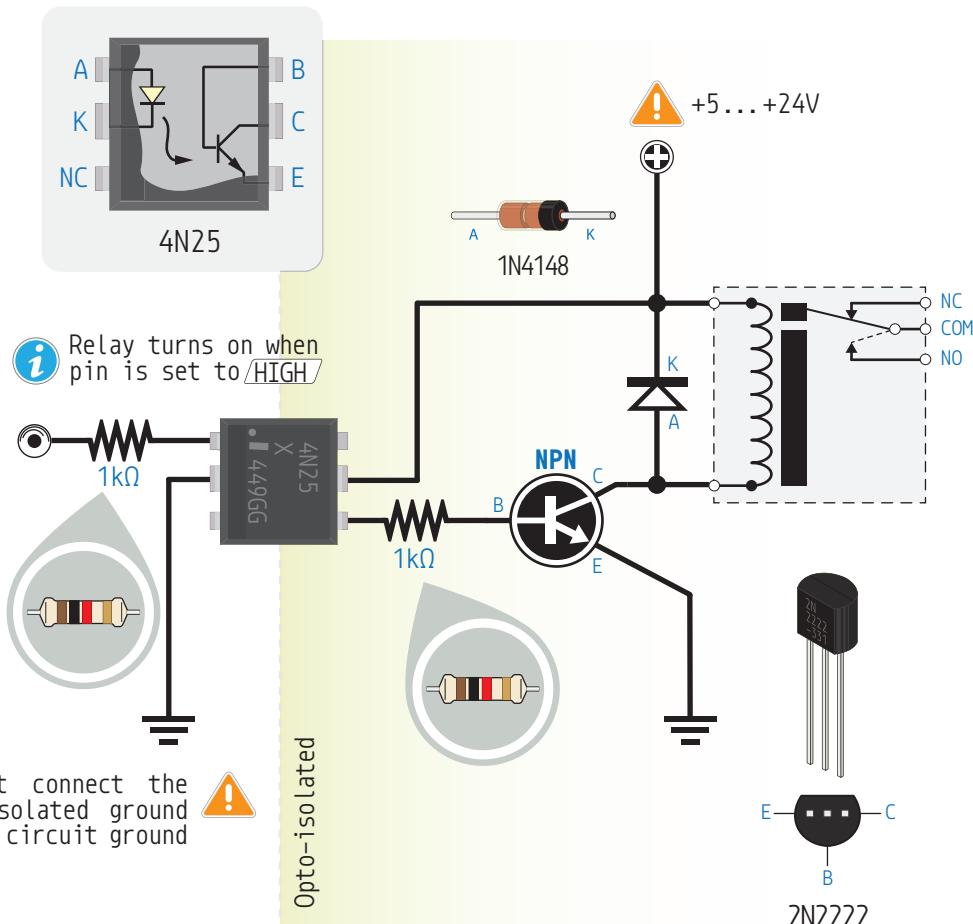
Relays offer complete isolation between the control circuit and the load. They can switch AC and DC and they can be very reliable and robust. Compared to transistors, relays are very slow. Relays are ON-OFF devices, whereas transistors can have their voltage drop varied.

Opto-Isolated Relay
Basic Connections

A   B
K   C
NC   E

4N25

⚠ +5...+24V

A   K
1N4148

NC
COM
NO

ℹ Relay turns on when pin is set to HIGH

1kΩ

4N25
X
449GG

K
A

NPN
C
B
E

1kΩ

⚠ Do not connect the opto-isolated ground to the circuit ground

Opto-isolated

2N
2222
331

E   C
B

2N2222

💡 The purpose of an optocoupler is to isolate two parts of a circuit. Typical examples are industrial units with lots of interferences which affect the signals in the wires. If these interferences are not isolated, they can affect the correct functioning of the unit and cause errors.
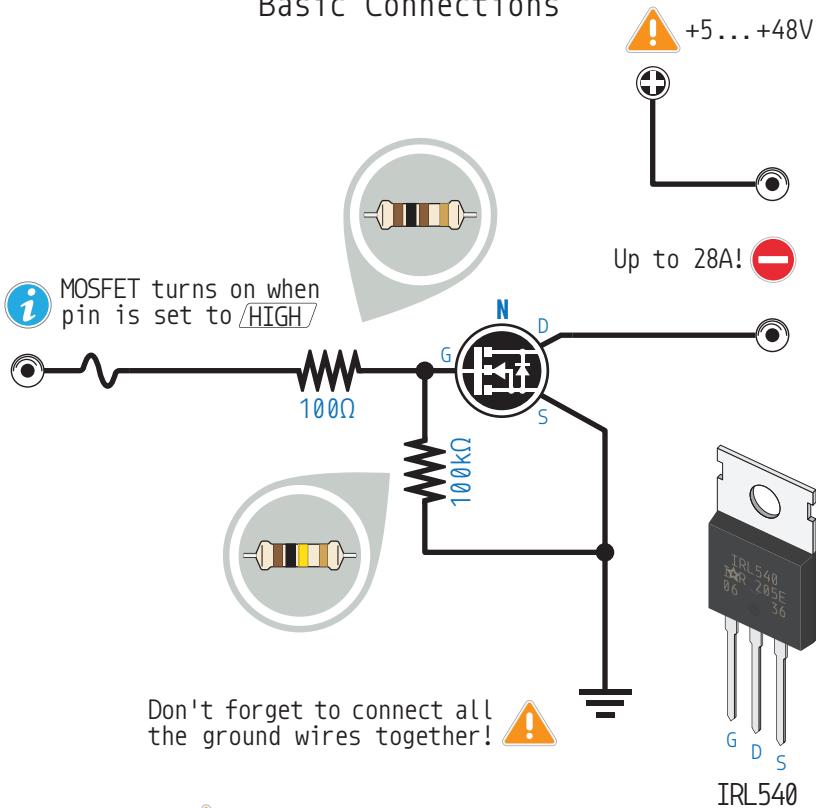
27

Logic-Level MOSFET
Basic Connections

⚠️ +5...+48V

⊕

Up to 28A! ⛔

ℹ️ MOSFET turns on when pin is set to HIGH

N

G

D

S

100Ω

100kΩ

IRL540
06 205E
06 36

G D S

IRL540

Don't forget to connect all the ground wires together! ⚠️

⚠️ Don't forget to attach a heat sink to the MOSFET if are connecting a high-power load!

💡 If you need to switch high-current and/or high-voltage loads with a microcontroller board, you need to use a MOSFET. This circuit is reccomended only for switching purposes or in low frequency applications. The IRL540 can deliver its specified 28A continuous current at 5V.

28
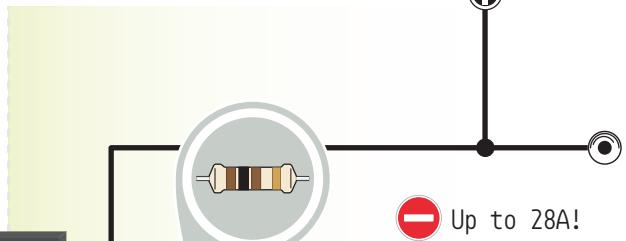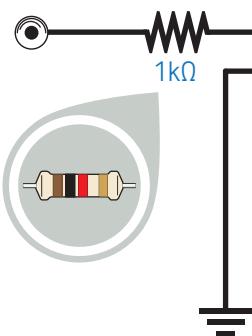
Non-Logic-Level MOSFET
Using the 4N25 Optocoupler

⚠ +12V

i MOSFET turns on when pin is set to /HIGH/

🚫 Up to 28A!

1kΩ

4N25
X
449GG

100Ω

G
N D

S

100kΩ

IRF540N
IR 836P
2E 31

G D S

IRF540

Do not connect the opto-isolated ground to the circuit ground ⚠

Opto-isolated

⚠ Don't forget to attach a heat sink to the MOSFET if are connecting a high-power load!
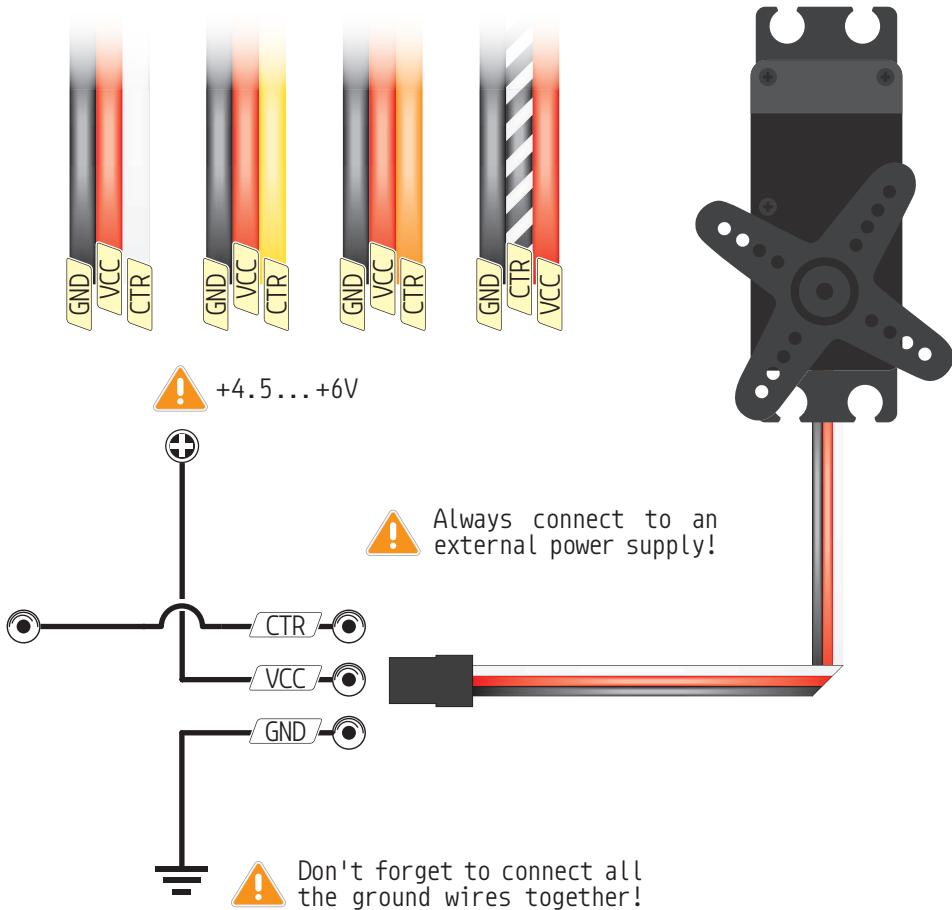
💡 Use this circuit if you have a power FET (like the IRF series) and need some galvanic separation from your microcontroller circuit. This circuit is reccomended only for switching purposes or in low frequency applications. The IRF540 can deliver its specified 28A of continuous current at 10V.

Servo
Basic Connections

GND VCC CTR

GND VCC CTR

GND VCC CTR

GND CTR VCC

⚠️ +4.5...+6V

⊕

⚠️ Always connect to an external power supply!

CTR

VCC

GND

⚠️ Don't forget to connect all the ground wires together!
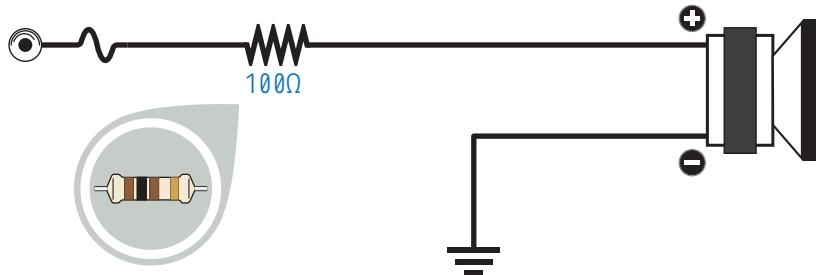
💡 Standard servos are designed to receive electronic signals that tell them what position to hold. They are used, for example, to control the position of flaps, rudders and steering. Continuous rotation servos on the other hand turn at certain speed and direction. They are useful for driving wheels and pulleys.

30
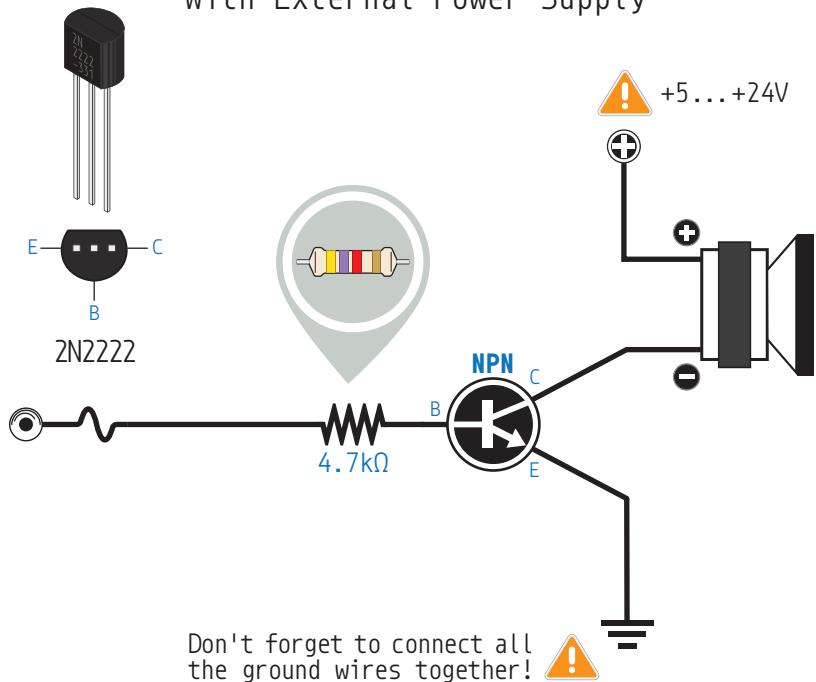
Magnetic Buzzer
Basic Connections

100Ω

+

−

With External Power Supply

2N2222

E — C

B

⚠ +5...+24V

+

+

−

NPN

B

4.7kΩ

C

E

Don't forget to connect all
the ground wires together! ⚠
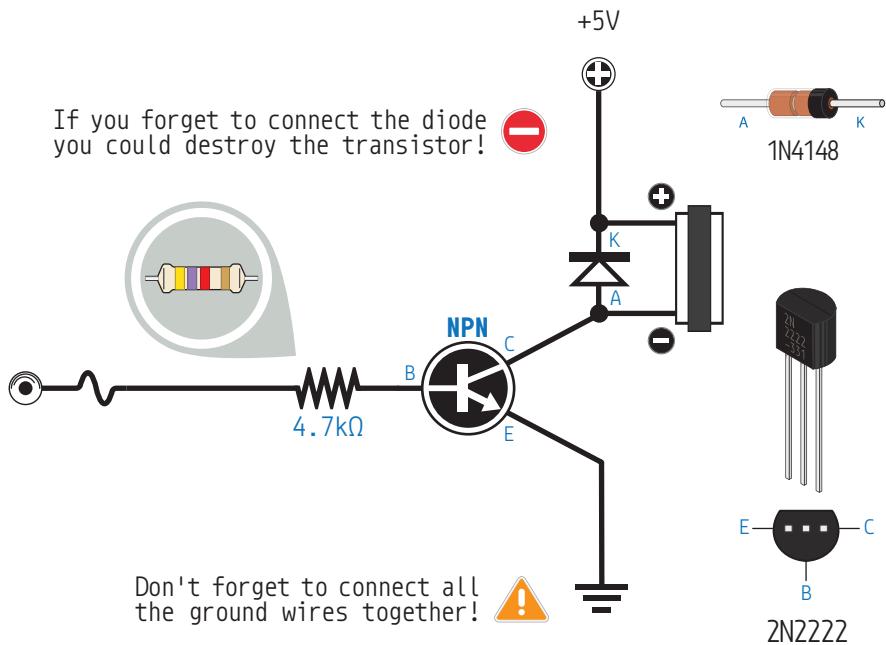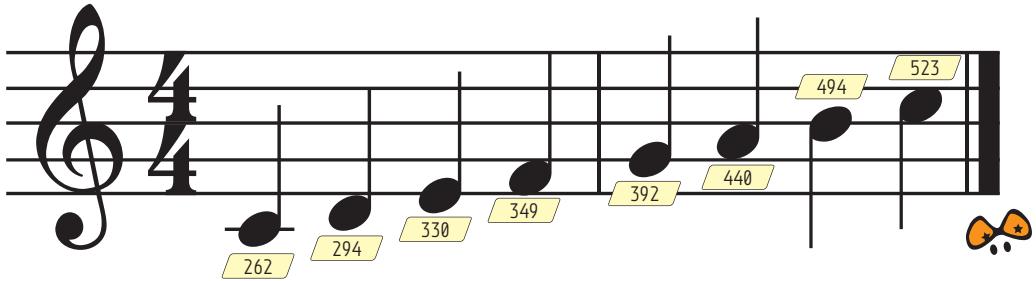
31

Piezo Buzzer
Basic Connections

+5V

If you forget to connect the diode
you could destroy the transistor! 🚫

A ———◯═— K
1N4148

K
A

NPN

B   C

4.7kΩ

E

Don't forget to connect all
the ground wires together! ⚠️

2N
2222
-331

E ●●● C

B

2N2222

Note Frequency (Hz)

262 294 330 349 392 440 494 523
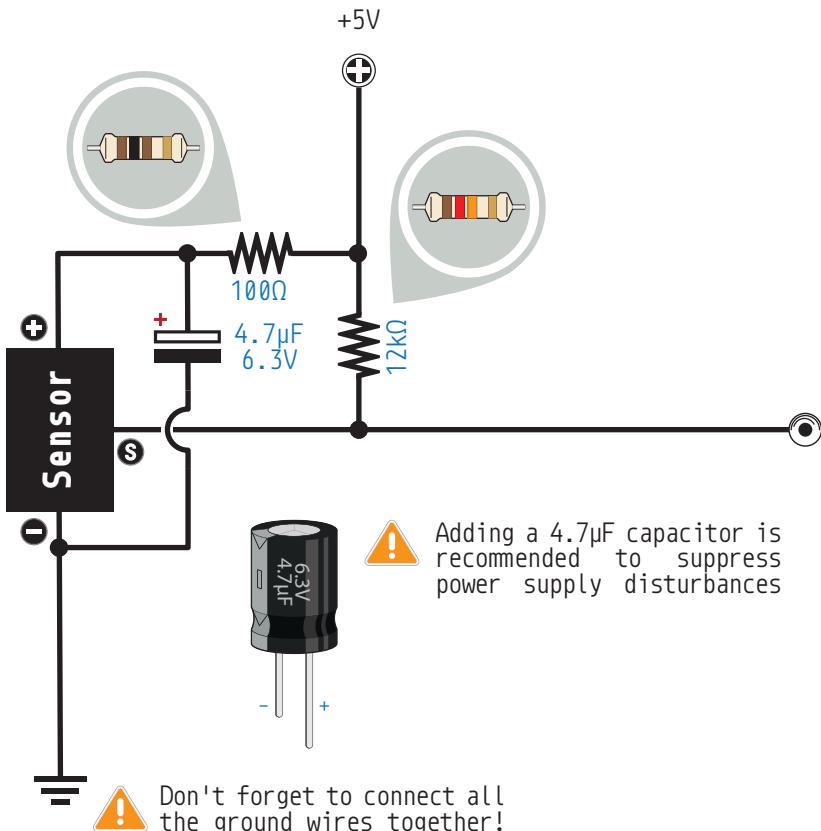
IR Detector
Basic Connections

+5V

Sensor

100Ω

4.7μF
6.3V

12kΩ

6.3V
4.7μF

− +

⚠ Adding a 4.7μF capacitor is recommended to suppress power supply disturbances

⚠ Don't forget to connect all the ground wires together!

IR detectors are tiny microchips with a photocell that are tuned to detect infrared light. They are almost always used for remote control detection. IR detectors are digital out, either they detect a signal over a carrier (usually 38kHz) and output LOW (0V) or they do not detect anything and output HIGH (5V).
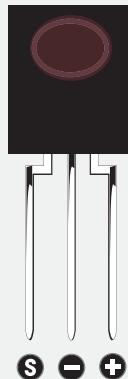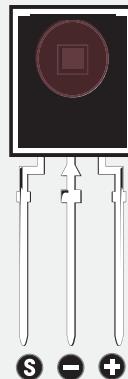
IR Detector
Common IR Detectors
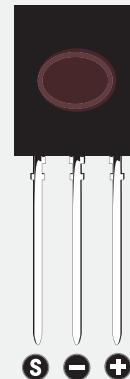
TSOP4836
SFH5110
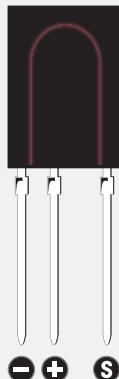
TSOP1836
NJL61H380

IS1U60

S − +

S − +

S − +
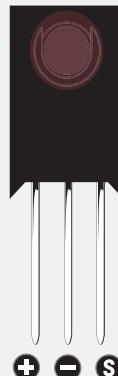
TSOP1736
SFH506
TFMS5360

SFH505A

PIC12043S

− + S

+ − S

S − +

33

IR Emitter
Basic Connections

+5V

NPN

B

C

K   A

33Ω

E

2.2kΩ

100nF

A   K

TSAL6200

2N2222

E   C

B

Don't forget to connect all the ground wires together! ⚠️

104 J100
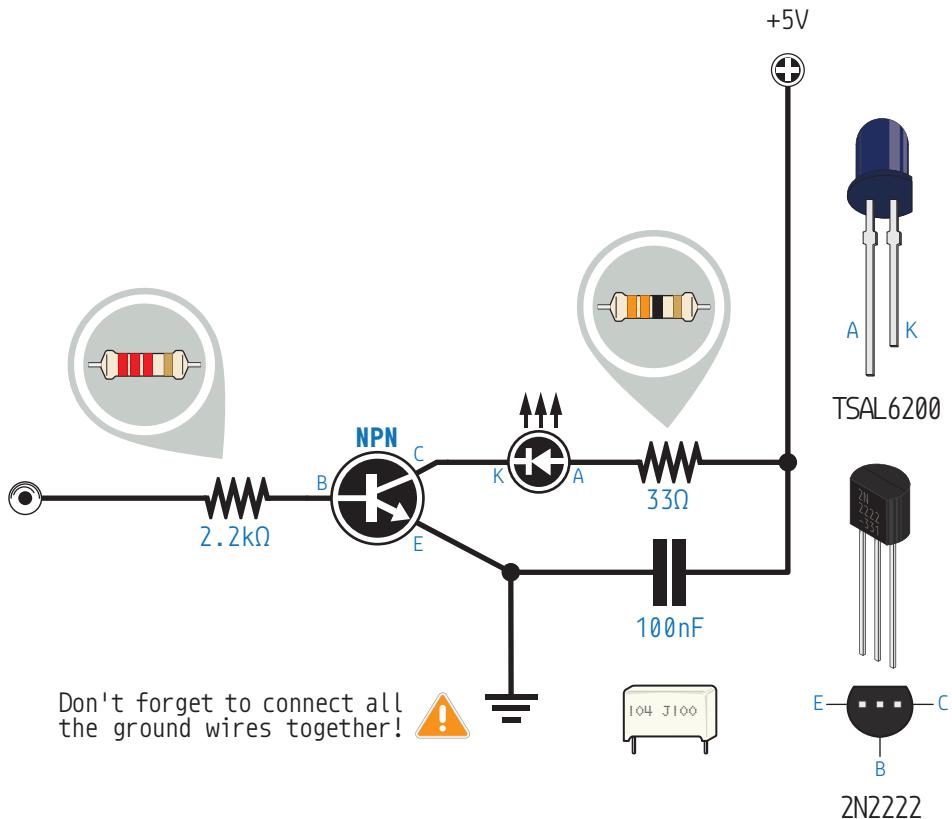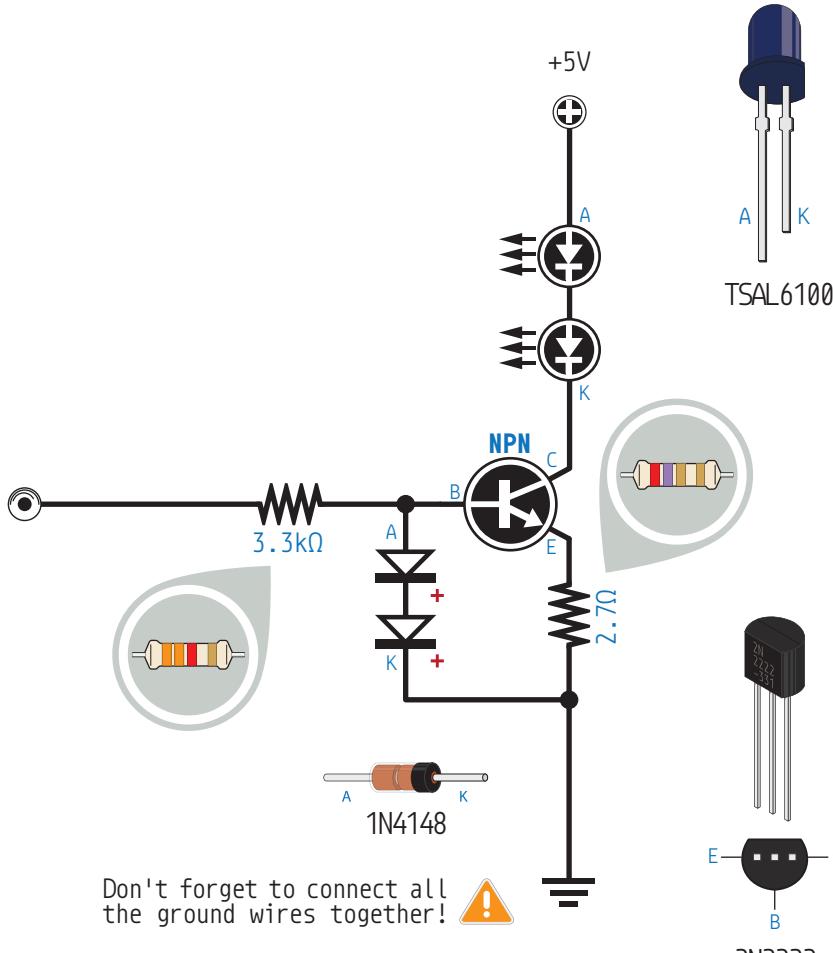
IR (infrared) communication is a popular, inexpensive, and easy to use wireless communication technology. IR light is very similar to visible light, except that it has a slightly longer wavelength. This means IR is undetectable to the human eye, making it perfect for wireless communication.

34
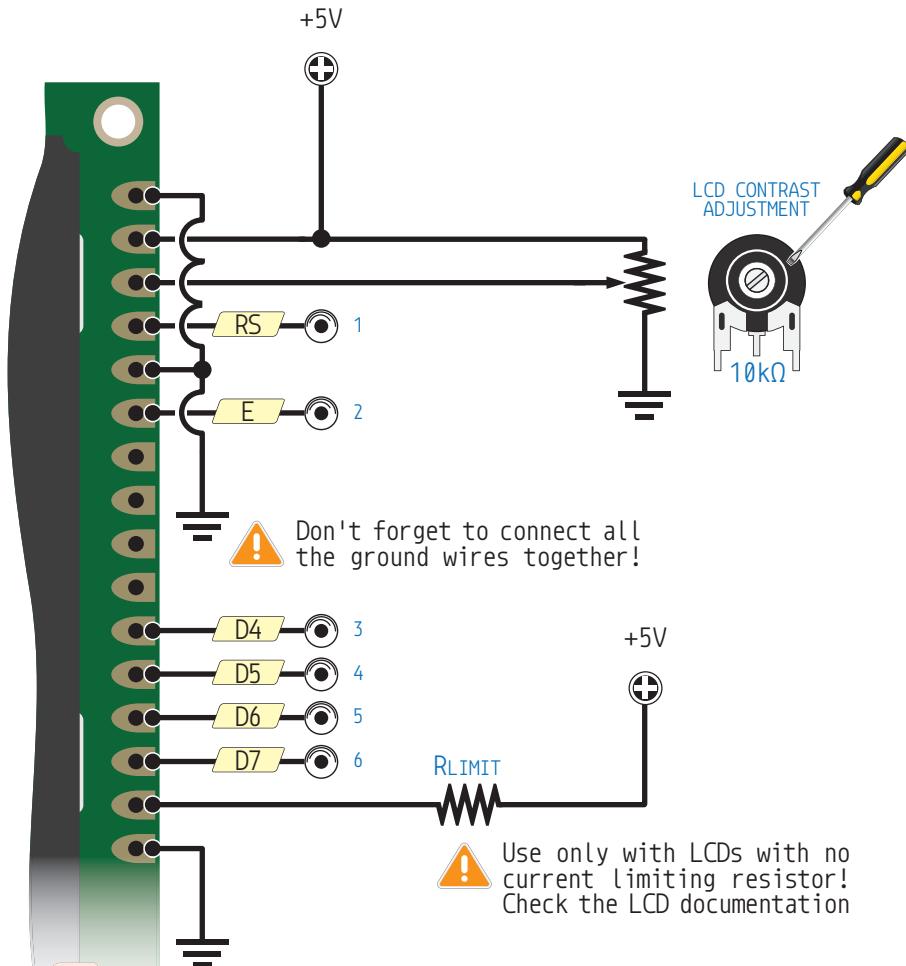
Constant-Current IR Emitter
Basic Connections

+5V

TSAL6100

A K

NPN

C

B

E

3.3kΩ

A

K

+

+

2.7Ω

1N4148

2N2222

E   C

B

Don't forget to connect all
the ground wires together!

HD44780-Based LCD
Basic Connections

+5V

LCD CONTRAST
ADJUSTMENT

RS   1

E   2

10kΩ

⚠ Don't forget to connect all
the ground wires together!

D4   3

D5   4

D6   5

D7   6

+5V

R_LIMIT

⚠ Use only with LCDs with no
current limiting resistor!
Check the LCD documentation
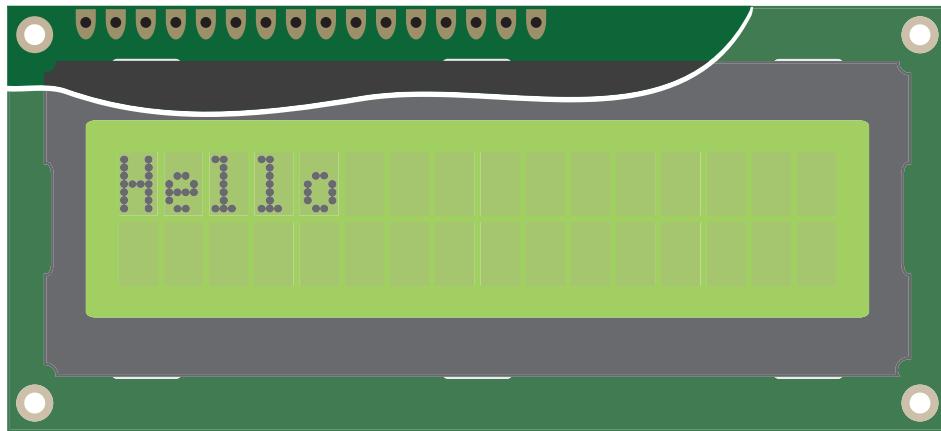
Normally the LCD backlight is composed of LEDs in series. The total voltage drop across the LEDs is tipically 4.2V and the recommended current through the LEDs is 120mA. You should use a current limit resistor **R_LIMIT** where:

$$R_{LIMIT} = (V_{BACKLIGHT}-4.2)/0.12$$

HD44780–Based LCD

Pinout
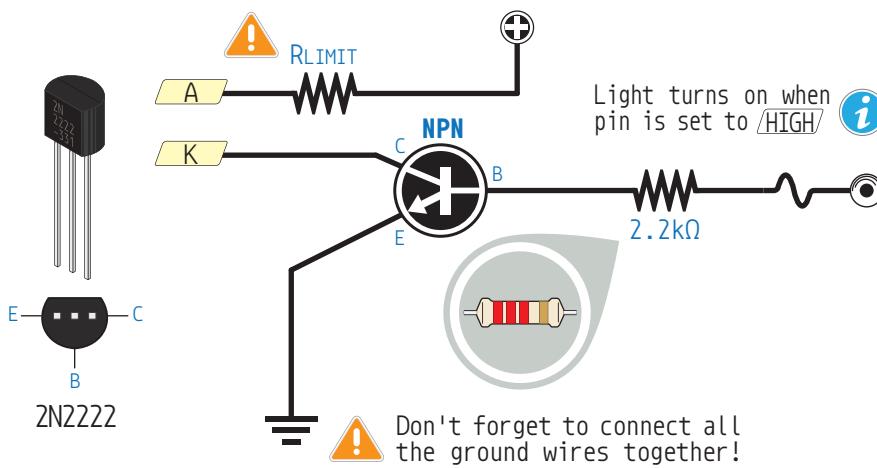
GND VDD VEE RS RW E D0 D1 D2 D3 D4 D5 D6 D7 A K

Hello

LCD Backlight Control
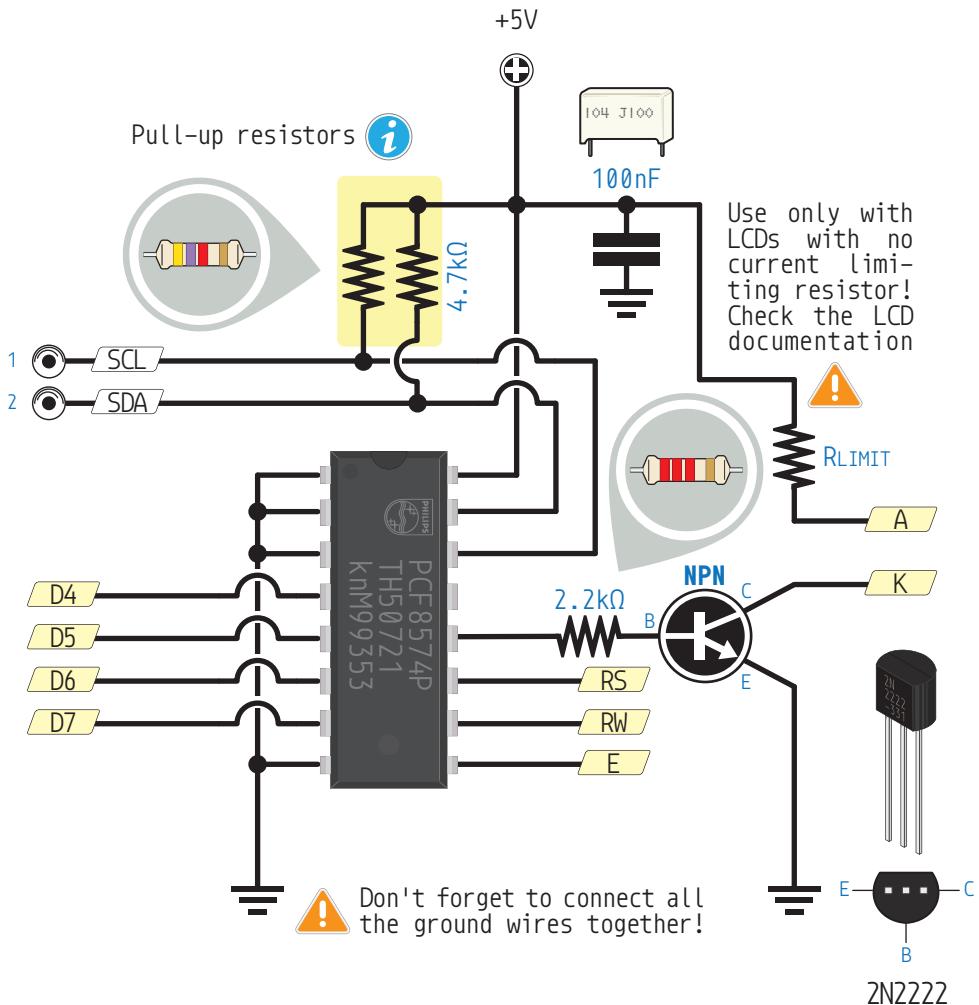
Use only with LCDs with no
current limiting resistor!
Check the LCD documentation

⚠

+5V ⊕

R_{LIMIT}

A ——/\\/\\/——

Light turns on when
pin is set to HIGH ⓘ

NPN

C

K ——

B

E

2.2kΩ

E ——■■■—— C

B

2N2222

⚠ Don't forget to connect all
the ground wires together!

HD44780-Based LCD Via I²C
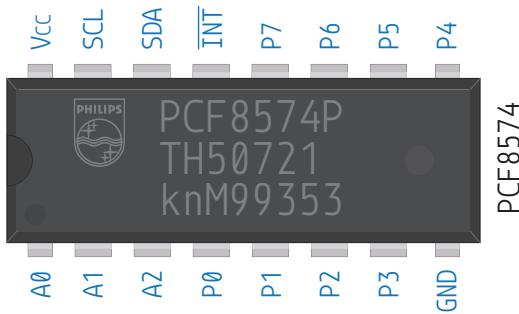
Using the PCF8574 I/O Expander

+5V

100nF

Pull-up resistors

4.7kΩ

Use only with LCDs with no current limiting resistor! Check the LCD documentation

1 SCL

2 SDA

PCF8574P
TH50721
KnM99353

R_{LIMIT}

A

NPN

2.2kΩ

B

C

K

E

D4

D5

D6

D7

RS

RW

E

Don't forget to connect all the ground wires together!

2N2222

E   C

B

2N2222

PCF8574
Pinout

Vcc SCL SDA INT P7 P6 P5 P4

PHILIPS
PCF8574P
TH50721
knM99353

PCF8574

A0 A1 A2 P0 P1 P2 P3 GND
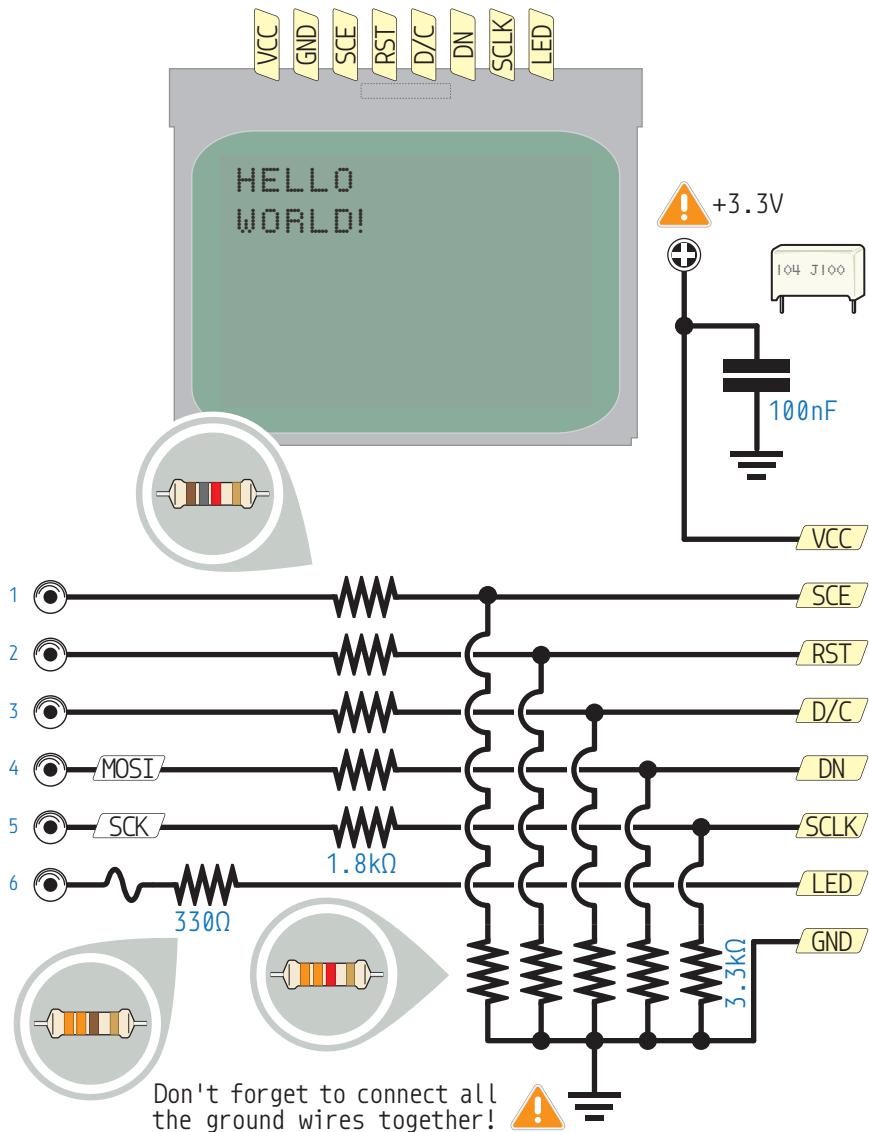
I^{2}C Pull-Up Resistors

I^{2}C is a popular communication protocol in embedded
systems. When interfacing with the slave device a
pull-up resistor is needed on each bi-directional
line. This is just two wires, called SCL and SDA.
SCL is the clock line that is used to synchronize
all data transfers over the I^{2}C bus. SDA is the data
line. The SCL and SDA lines are connected to all de-
vices on the I^{2}C bus. There needs to be a third wire
which is just the ground. Both SCL and SDA lines are
"open drain" drivers. What this means is that the
chip can drive its output low, but it cannot drive
it high. For the line to be able to go high you must
provide pull-up resistors to the 5V supply. There
should be a resistor from the SCL line to the 5V
line and another from the SDA line to the 5V line.
You only need one set of pull-up resistors for the
whole I^{2}C bus, not for each device.

37

Nokia 5110 LCD
Basic Connections
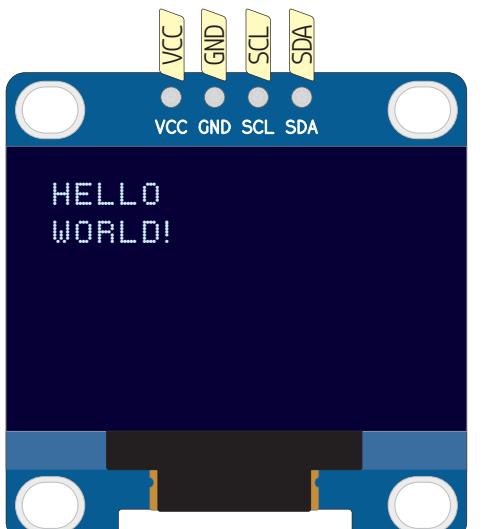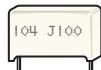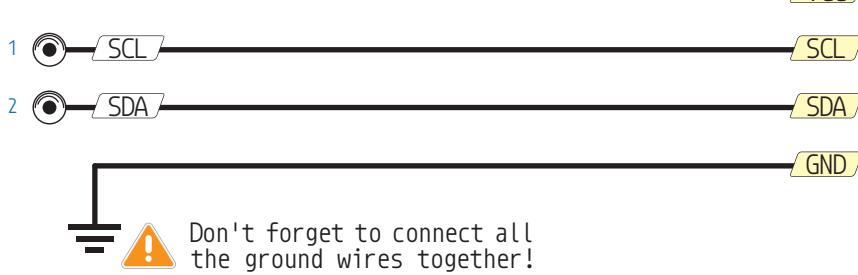
VCC GND SCE RST D/C DN SCLK LED

HELLO
WORLD!

⚠ +3.3V

104 J100

100nF

VCC

1 ─ SCE

2 ─ RST

3 ─ D/C

4 MOSI ─ DN

5 SCK ─ SCLK

1.8kΩ

6 ─ LED

330Ω

3.3kΩ

GND

Don't forget to connect all
the ground wires together! ⚠

38

OLED LCD
Basic Connections

VCC GND SCL SDA

VCC GND SCL SDA

HELLO
WORLD!

⚠ +3.3V
⊕

100nF

104 J100

VCC

1 ◉ SCL   SCL

2 ◉ SDA   SDA

GND

⚠ Don't forget to connect all
the ground wires together!

39
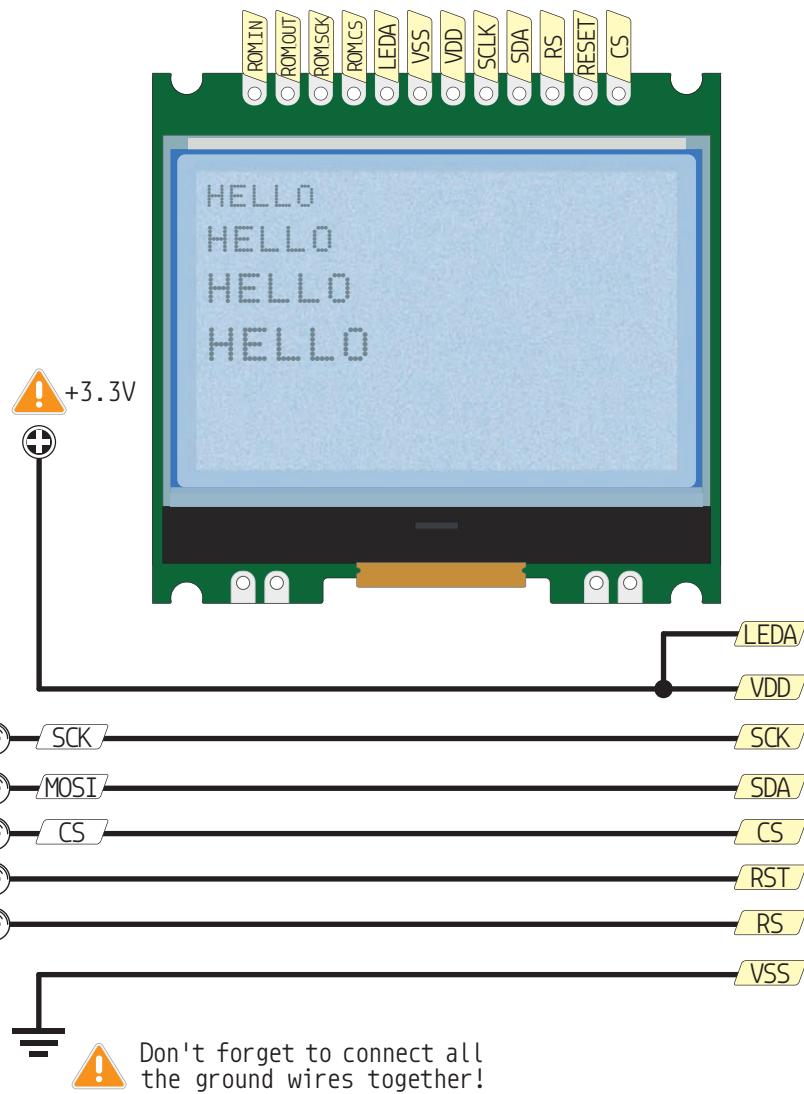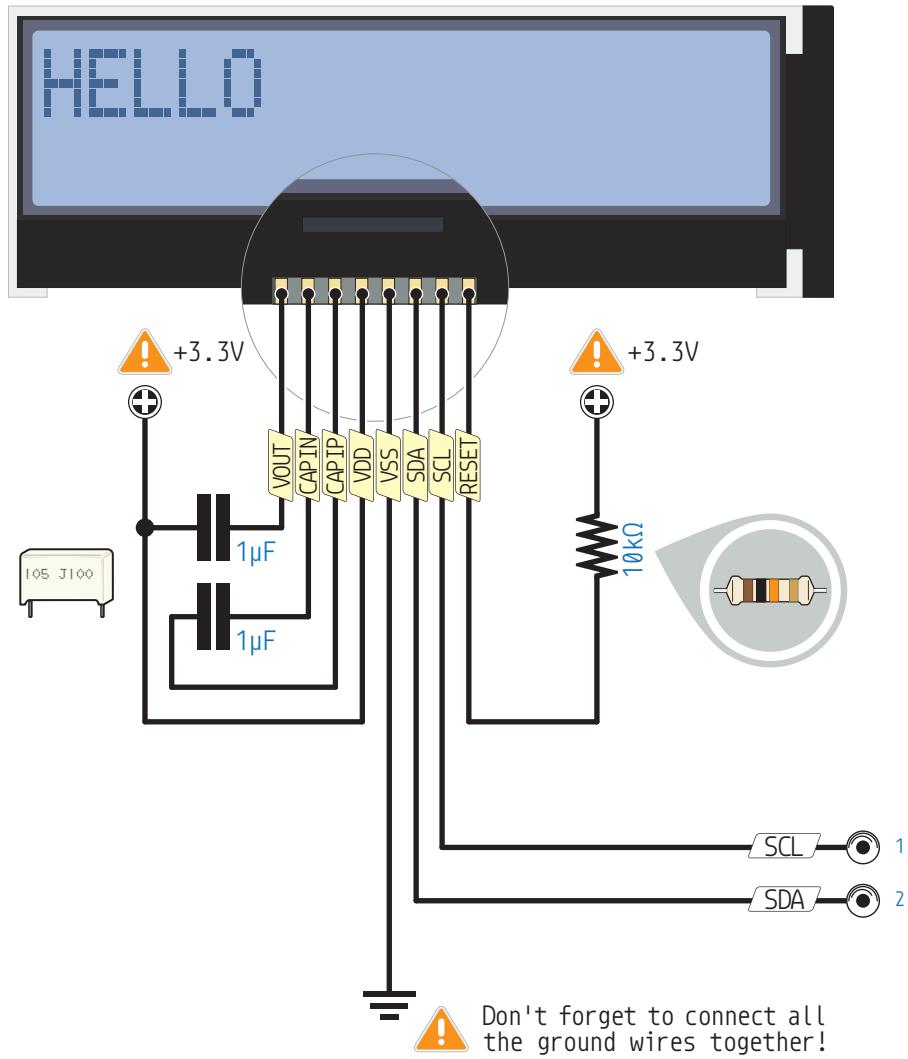
UC1701 128x64 LCD
Basic Connections

ROM IN | ROM OUT | ROM SCK | ROM CS | LEDA | VSS | VDD | SCLK | SDA | RS | RESET | CS

HELLO
HELLO
HELLO
HELLO

⚠ +3.3V

LEDA

VDD

1 SCK — SCK

2 MOSI — SDA

3 CS — CS

4 — RST

5 — RS

VSS

⚠ Don't forget to connect all
the ground wires together!

40
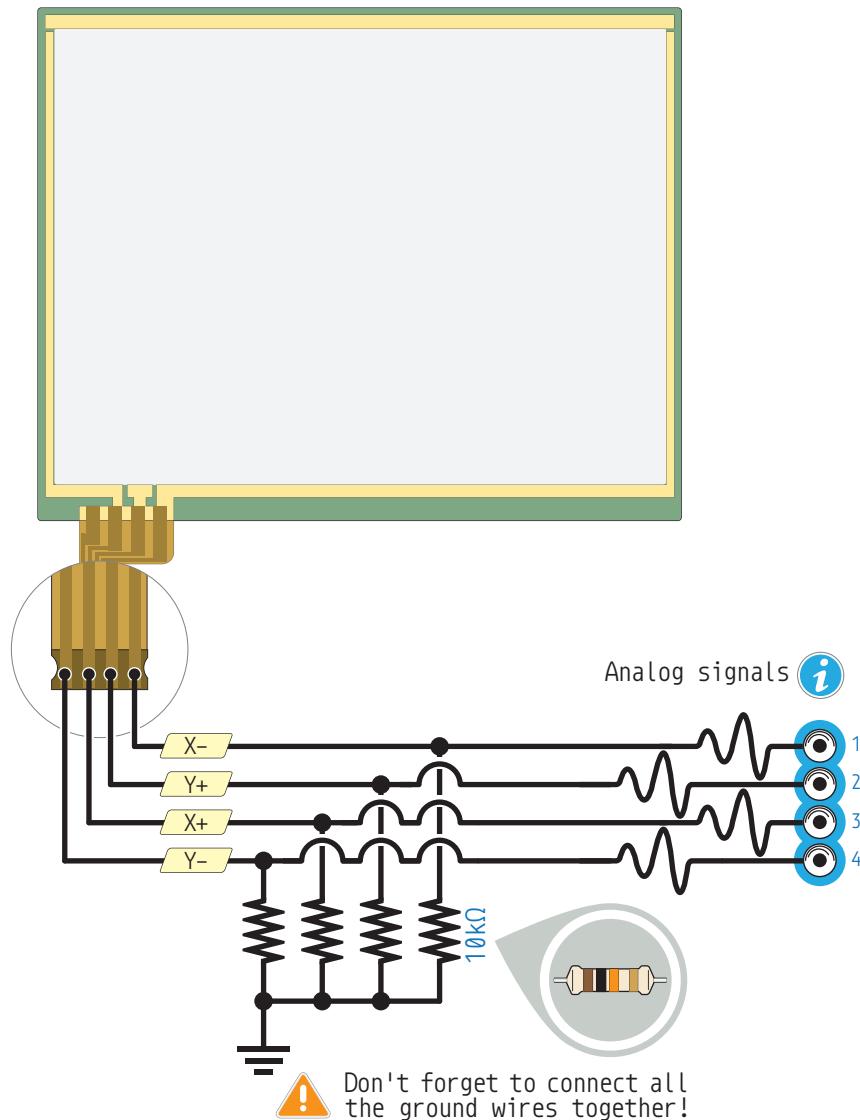
ST7032i LCD
Basic Connections

HELLO

⚠ +3.3V

⚠ +3.3V

VOUT
CAPIN
CAP1P
VDD
VSS
SDA
SCL
RESET

105 J100

1µF

1µF

10kΩ

SCL — ◉ 1

SDA — ◉ 2

⚠ Don't forget to connect all the ground wires together!
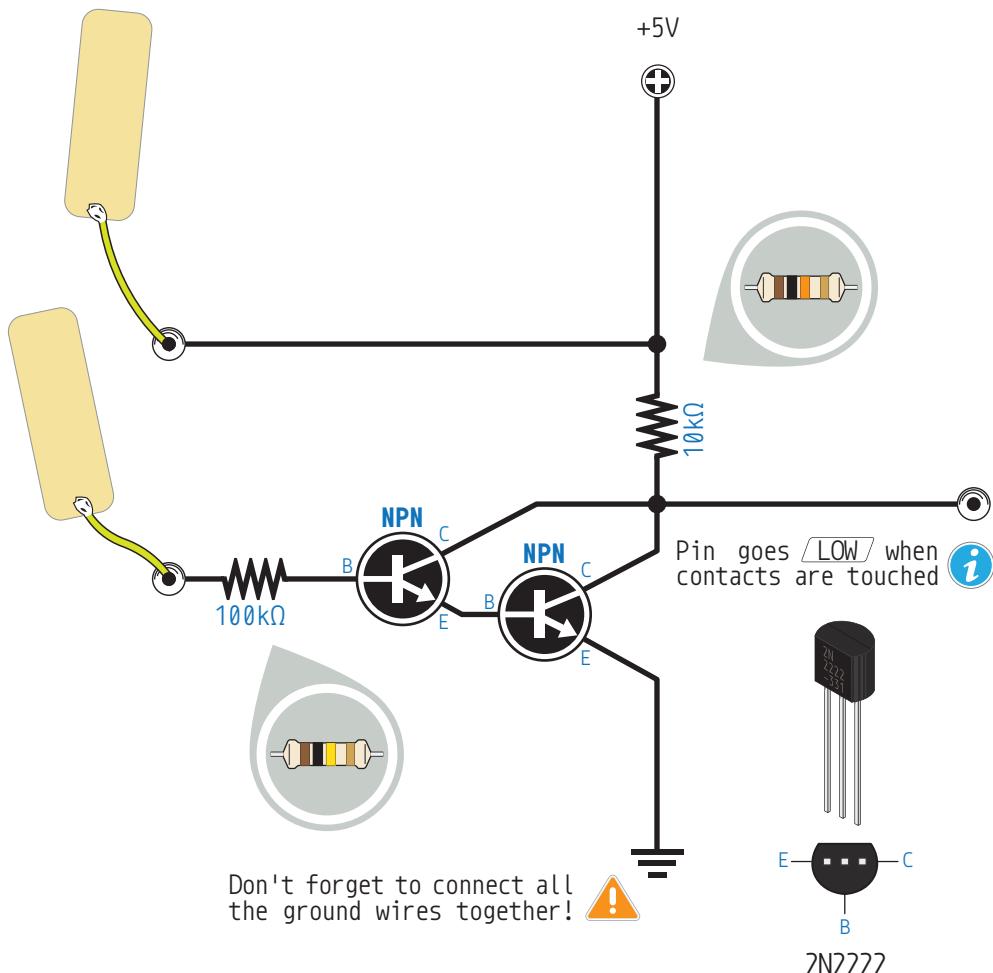
DS Touchscreen
Basic Connections

Analog signals ⓘ

X−
Y+
X+
Y−

1
2
3
4

10kΩ

Don't forget to connect all the ground wires together!

42

Simple Touch Sensor
Basic Connections

+5V

10kΩ

NPN
C
B
E

NPN
C
B
E

100kΩ

Pin goes LOW when contacts are touched

Don't forget to connect all the ground wires together!

E —•••— C

B

2N2222
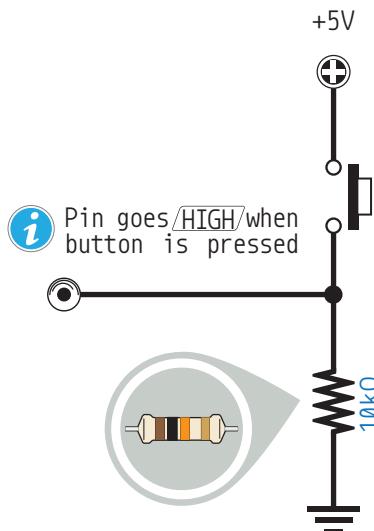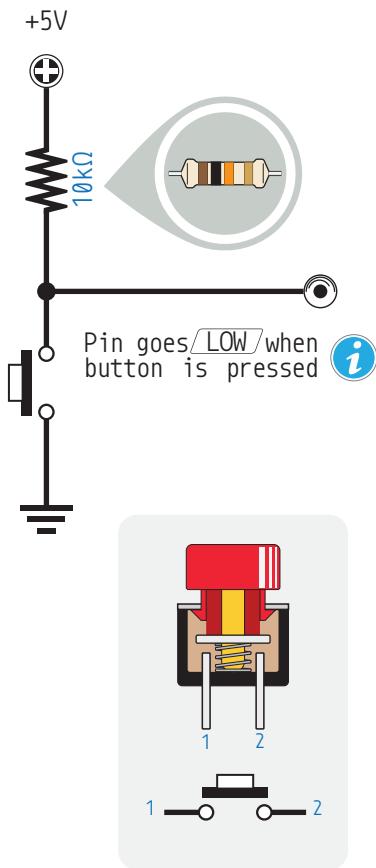
This simpe touch sensor is based on a Darlington configuration of transistors. They behave like a single transistor with a very high current gain, making it sensitive enough to respond to the small current passing through your body when you touch the metallic plates, activating the circuit.

43

Pushbutton
Basic Connections

+5V

10kΩ

Pin goes ⟋LOW⟋ when button is pressed ⓘ

1 2

1 ── ○   ○ ── 2

+5V

Pin goes ⟋HIGH⟋ when button is pressed ⓘ

10kΩ

Don't forget to connect all the ground wires together! ⚠

Pushbuttons or switches connect two points in a circuit when you press them. If you don't use the pull-up or pull-down resistor, the input pin is "floating" and will randomly return either HIGH or LOW values. Don't forget to connect all the ground wires together!

43

Pushbutton
Test Code

```
int LEDPin = 13;
int SWITCHPin = 4;
int val;

void setup() {
    pinMode(LEDPin,OUTPUT);
    pinMode(BUTTONPin,INPUT);
}


void loop() {
    val = digitalRead(SWITCHPin);
    if (val == LOW) {
        digitalWrite(LEDPin,HIGH);
    }
    if (val == HIGH) {
        digitalWrite(LEDPin,LOW);
    }
}
```

Assign variable *LEDPin* as pin 13
Assign variable *SWITCHPin* as pin 4
Variable for reading the pin status

Initialize the pin as an *OUTPUT*
Initialize the pin as an *INPUT*

Read input value and store it in *val*
Check if the button is pressed
Turn LED on
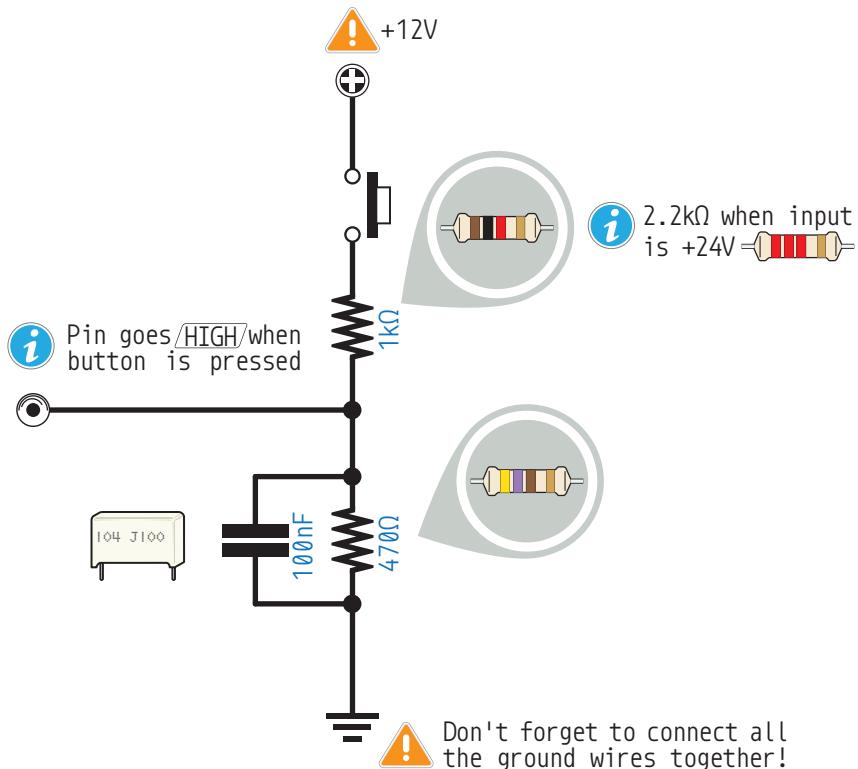
Check if the button is not pressed
Turn LED off

Using Internal Pull-Up Resistors

Pin goes /HIGH/ when
button is pressed *i*

Don't forget to connect all
the ground wires together!

44

Pushbutton to 12V
Basic Connections

⚠ +12V

2.2kΩ when input
is +24V

Pin goes /HIGH/ when
button is pressed

1kΩ

104 J100

100nF

470Ω

⚠ Don't forget to connect all
the ground wires together!
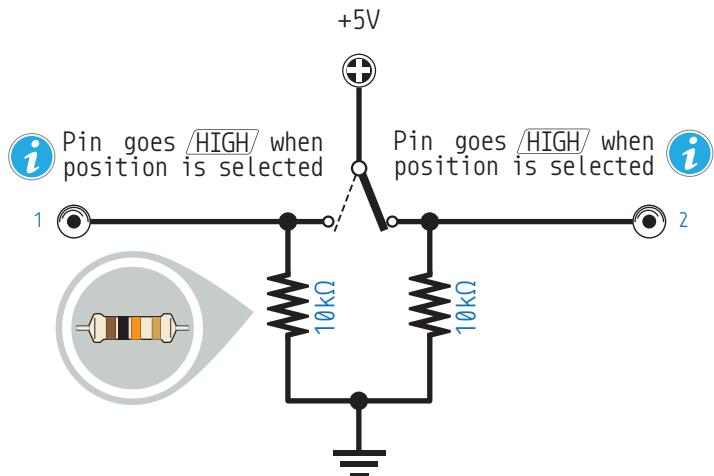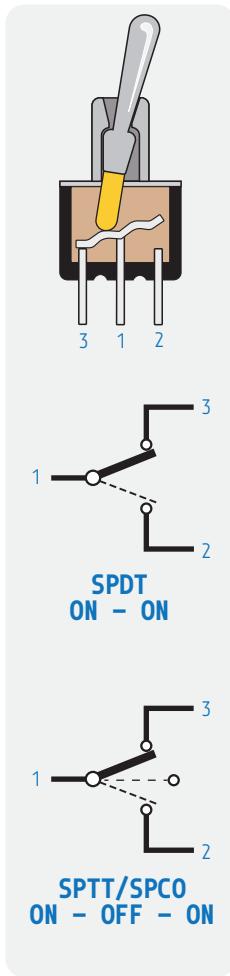
12V signals are often found in many electronic systems and appliances, as signal
voltage swings of 12V are advantageous to increase noise immunity. Electronic
noise captured by the input wiring will be reduced by about 2/3 thanks to the
resistor divider. Noise can be further reduced by the 100nF capacitor.
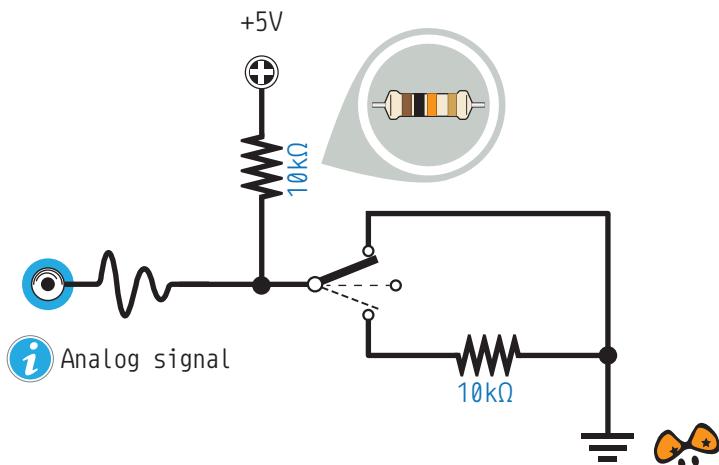
Toggle Switch
Basic Connections

45

+5V

(i) Pin goes /HIGH/ when position is selected

Pin goes /HIGH/ when position is selected (i)

1

2

10kΩ   10kΩ

3 1 2

SPDT
ON – ON

1

3

2

SPTT/SPCO
ON – OFF – ON

1

3

2

Using One Analog Input

+5V

10kΩ

(i) Analog signal

10kΩ

46
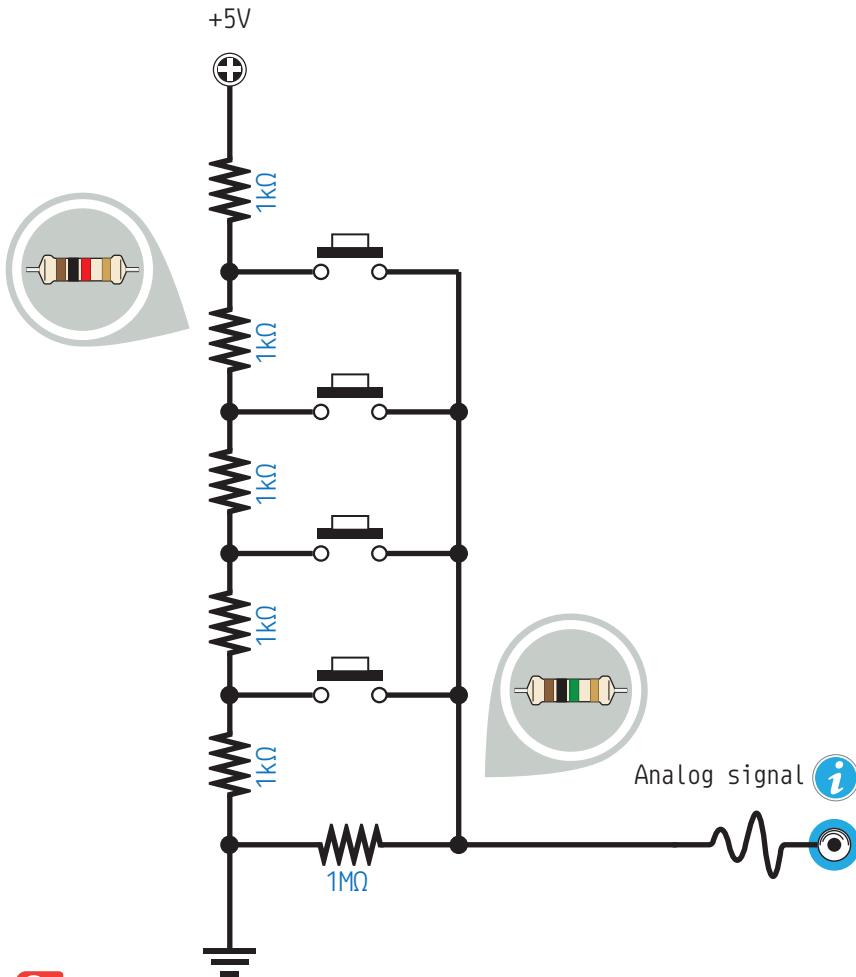
Multiple Pushbuttons
Basic Connections

+5V

1kΩ

1kΩ

1kΩ

1kΩ

1kΩ

1MΩ

Analog signal ⓘ
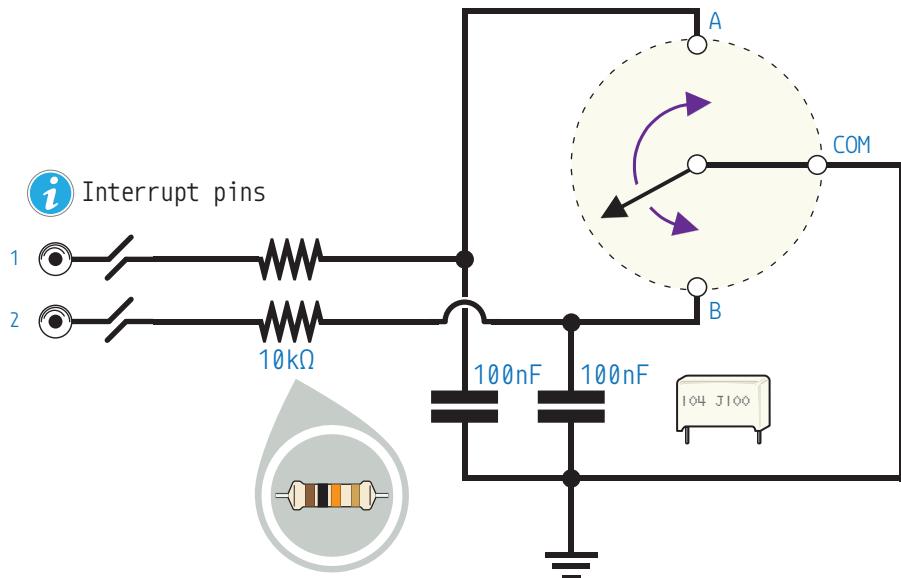
This circuit cannot handle simultaneous button presses. In order to do that, you could use resistors with values at 2x increments with respect to the previous one (e.g., 1kΩ, 2kΩ, 4kΩ, 8kΩ). Hence by checking the voltage value, you should be able to tell which buttons are pressed simultaneously.
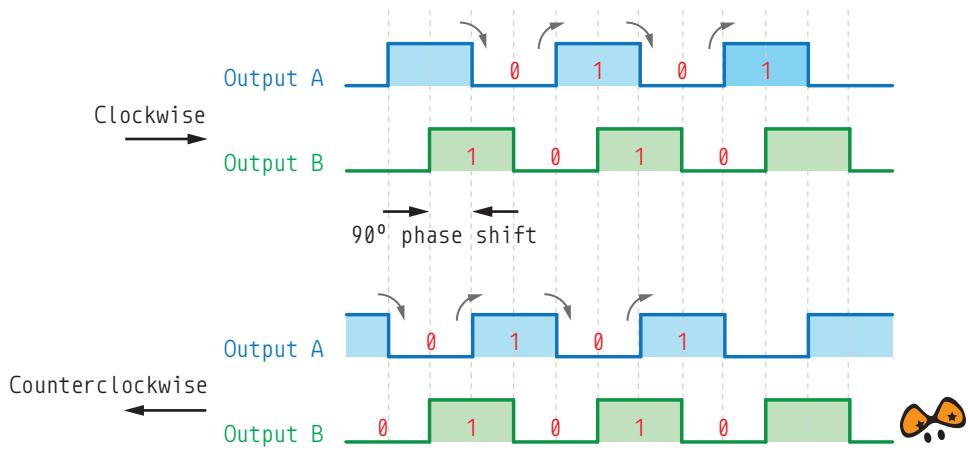
Rotary Encoder
Using Internal Pull-Up Resistors

ℹ️ Interrupt pins

A

COM

1

2

B

10kΩ

100nF 100nF

104 J100
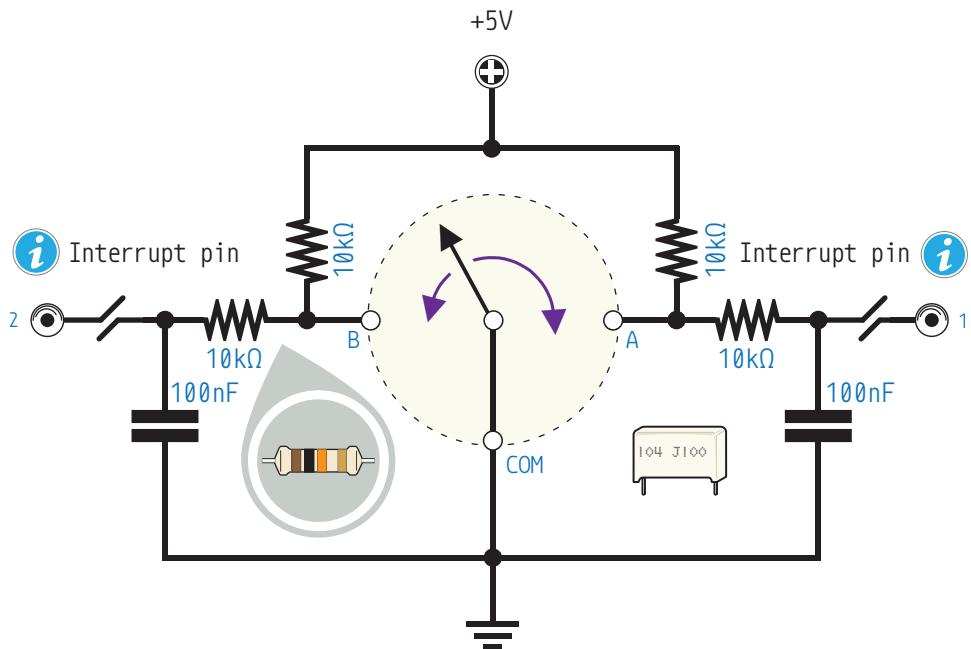
How Rotary Encoders Work

Output A   0   1   0   1

Clockwise

Output B   1   0   1   0

90° phase shift

Output A   0   1   0   1

Counterclockwise

Output B   0   1   0   1   0
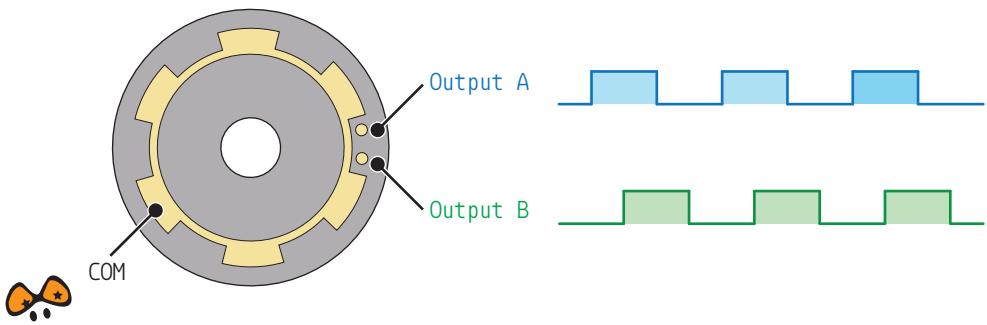
Rotary Encoder
Basic Connections

+5V

Interrupt pin

10kΩ

2

10kΩ

B

100nF

Interrupt pin

10kΩ

10kΩ

A

100nF

1

COM

104 J100

Inside a Rotary Encoder

Output A

Output B

COM
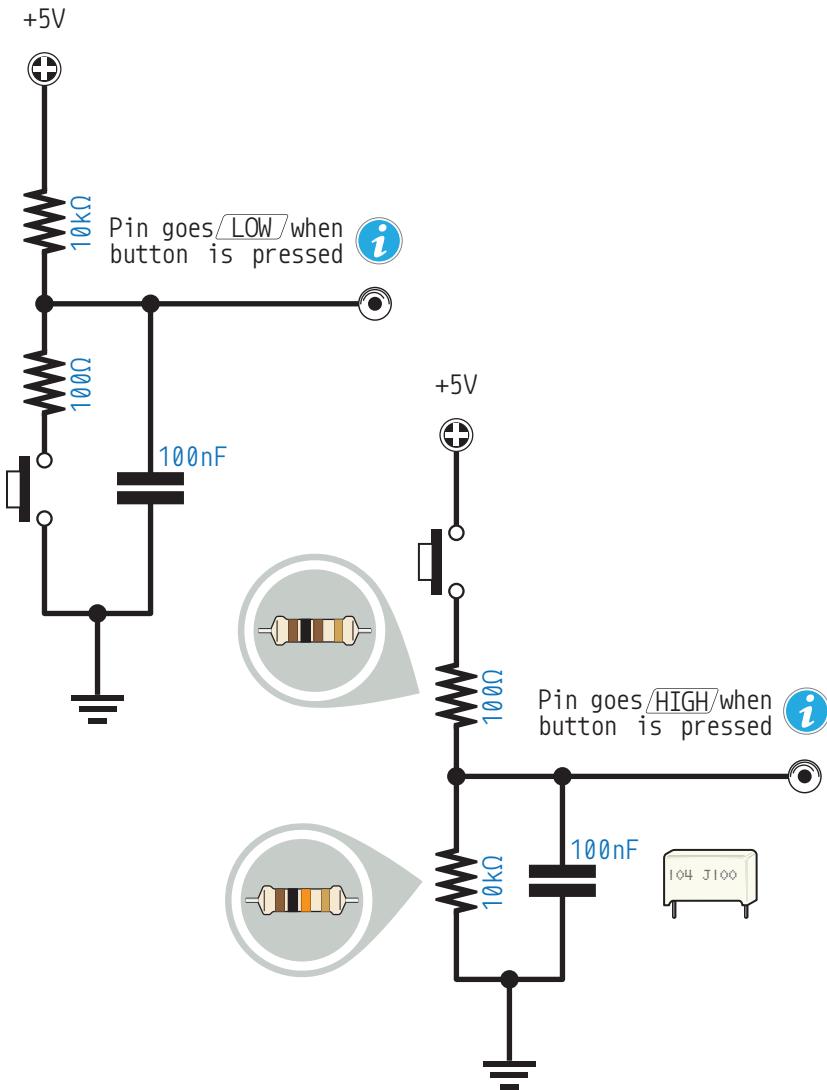
49

Simple Debouncing Circuit
Basic Connections

+5V

10kΩ

Pin goes /LOW/ when
button is pressed ℹ️

100Ω

100nF

+5V

100Ω

Pin goes /HIGH/ when
button is pressed ℹ️

10kΩ

100nF

104 J100
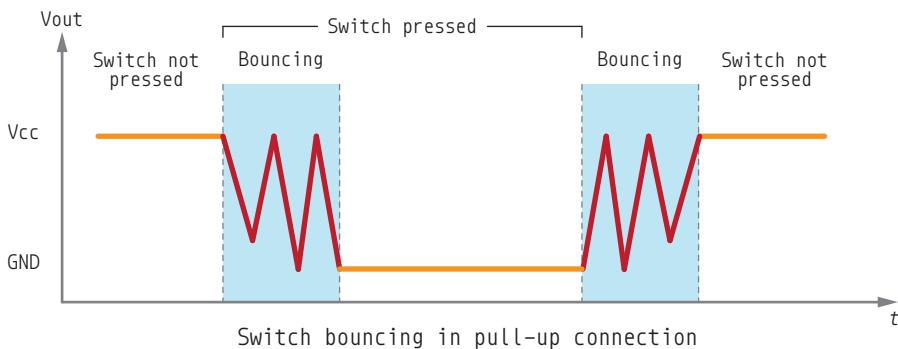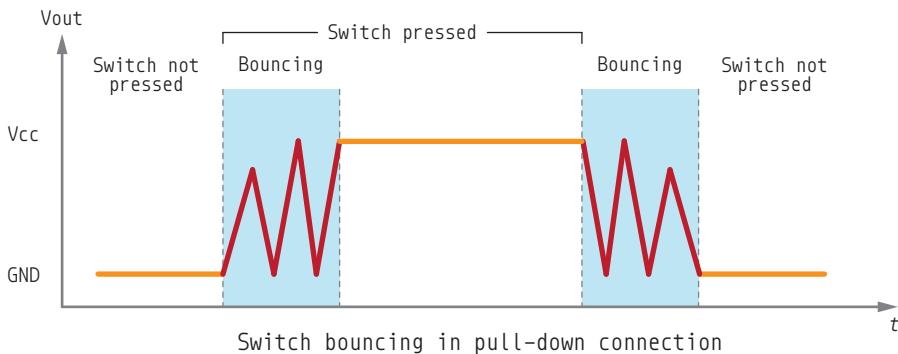
Debouncing

Theory

Contact bounce is a common problem associated with mechanical switches and relays. Switch and relay contacts are made up of spring metals which are forced to contact each other by an actuator. While they collide with each other there is a possibility of rebounding for some time before they make a stable contact. As a result of this effect there will be ON/OFF transitions generated as the contacts rapidly open and close. Contact bounce is an undesired behavior which generates multiple transitions for a single user input.

Switch bouncing in pull-down connection

Switch bouncing in pull-up connection
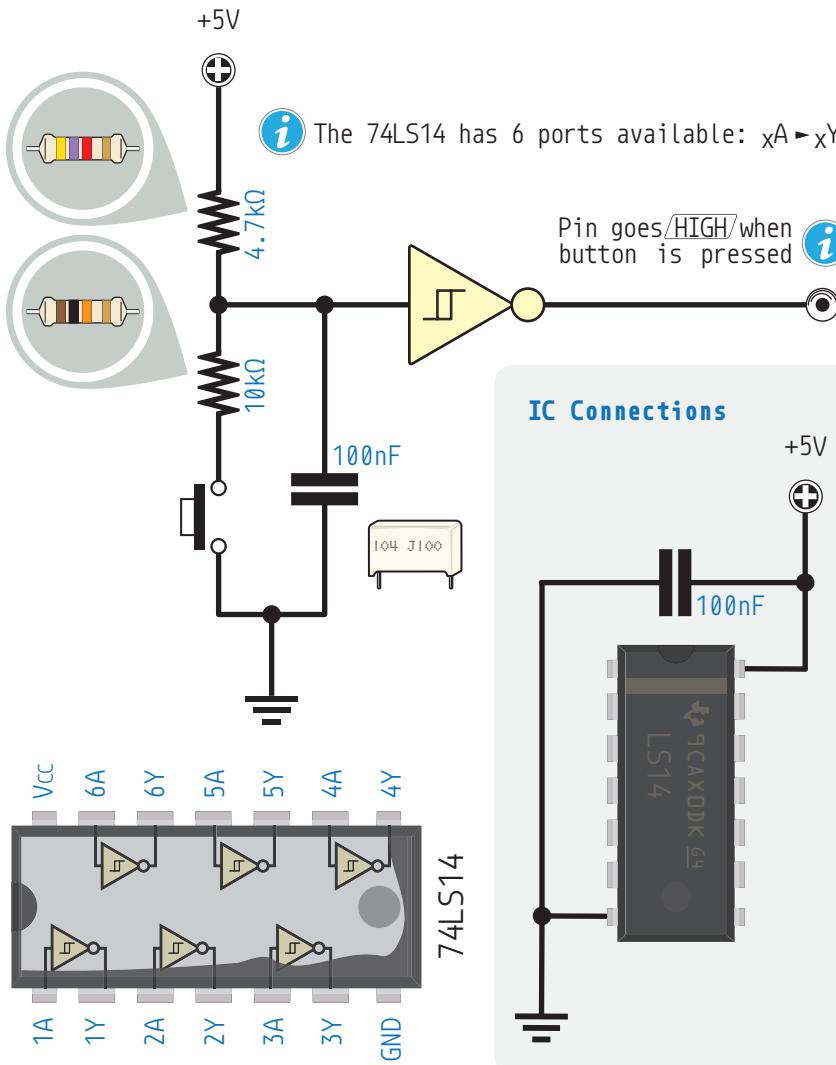
51
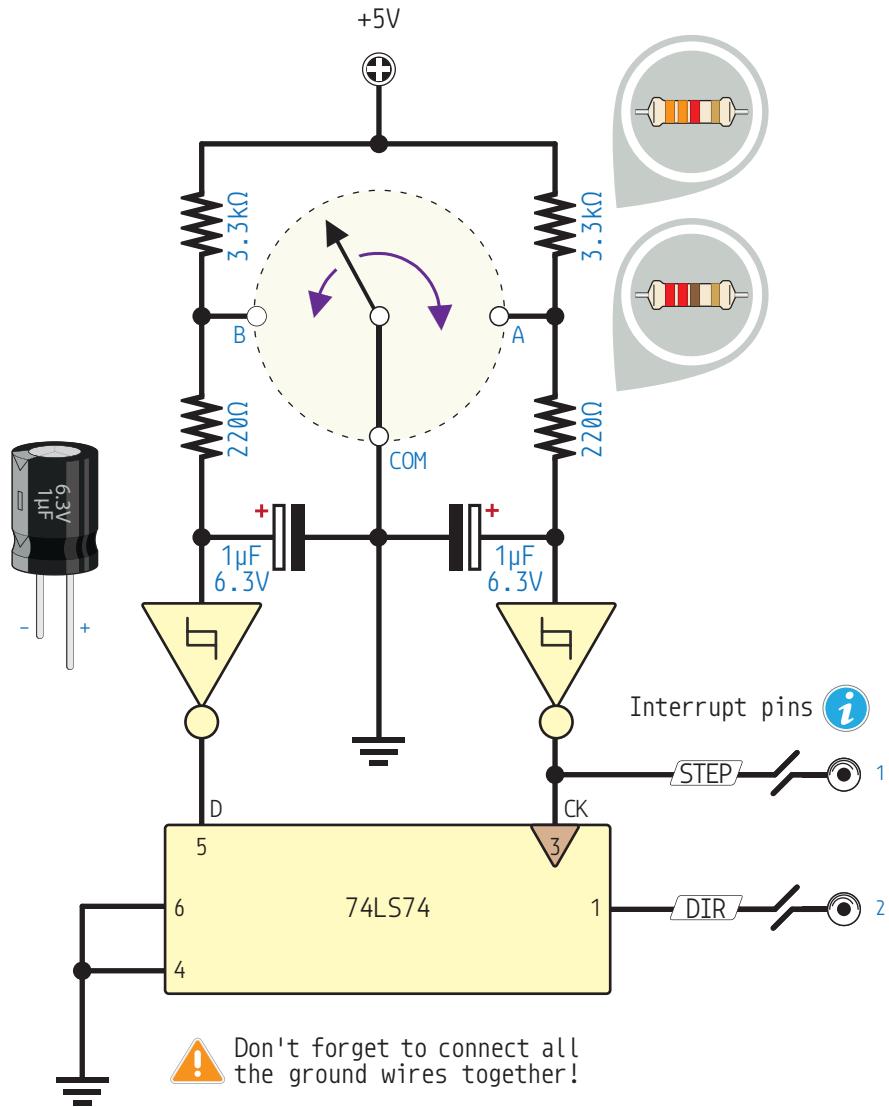
Debouncing

Using the 74LS14 Schmitt Trigger Inverter

+5V

ⓘ The 74LS14 has 6 ports available: $_xA \blacktriangleright _xY$

4.7kΩ

Pin goes /HIGH/ when ⓘ
button is pressed

10kΩ

100nF

104 J100

IC Connections

+5V

100nF

♦9CAXODK G4
LS14

Vcc 6A 6Y 5A 5Y 4A 4Y

74LS14

1A 1Y 2A 2Y 3A 3Y GND

Rotary Encoder Debouncing
Using the 74LS14 & the 74LS74

+5V

3.3kΩ

3.3kΩ

B

A

COM

220Ω

220Ω

6.3V
1µF

+
1µF
6.3V

+
1µF
6.3V

−   +

D

CK

Interrupt pins ⓘ

STEP   1

5

6

3

4

74LS74

1

DIR   2

Don't forget to connect all
the ground wires together!
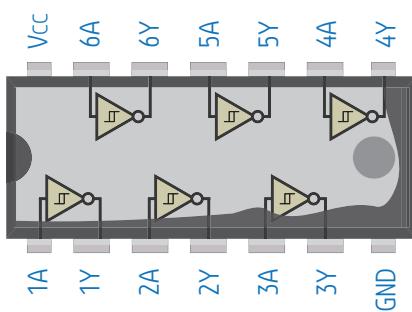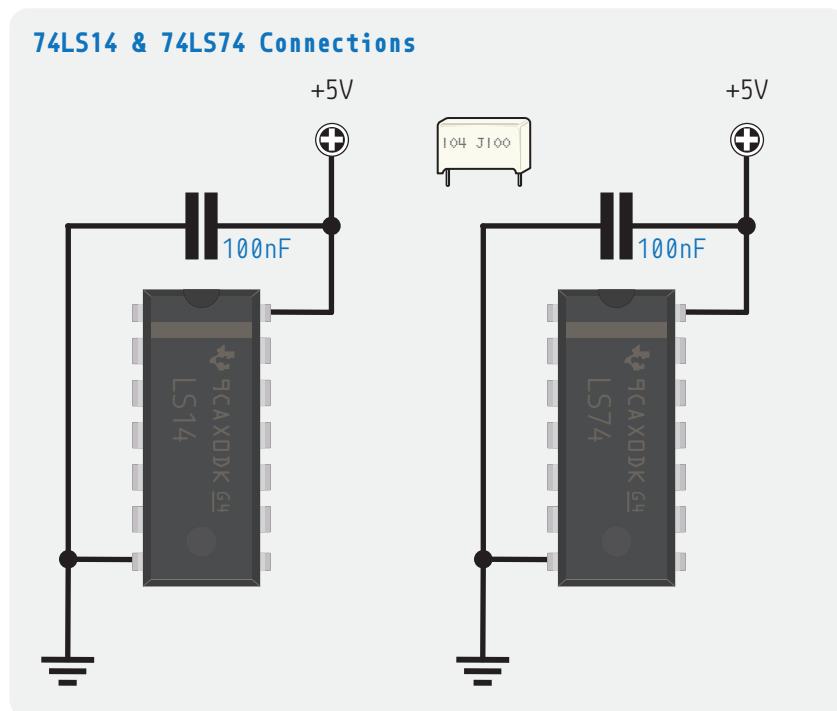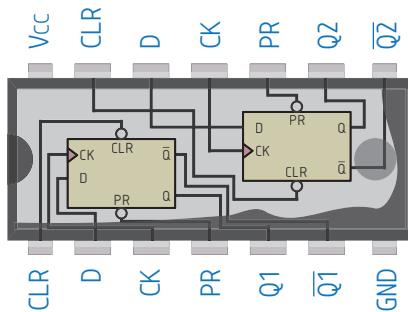
74LS14 & 74LS74

Pinout

74LS14 & 74LS74 Connections

+5V

104 J100

100nF

+5V

100nF

LS14

LS74

74LS14

| Vcc | 6A | 6Y | 5A | 5Y | 4A | 4Y |

| 1A | 1Y | 2A | 2Y | 3A | 3Y | GND |

74LS74

| Vcc | CLR | D | CK | PR | Q2 | Q̄2 |

| CLR | D | CK | PR | Q1 | Q̄1 | GND |

53

Keypad
Basic Connections

1N4148

1
2
3

4
5
6
7

8

K K K
A A A

ℹ Interrupt pin   ℹ Optional interrupt circuit

Keypad
Pinout

1	2	3
4	5	6
7	8	9
*	0	#

ROW0 — 2
ROW1 — 7
ROW2 — 6
ROW3 — 4

COL0 — 3
COL1 — 1
COL2 — 5

1 · 7
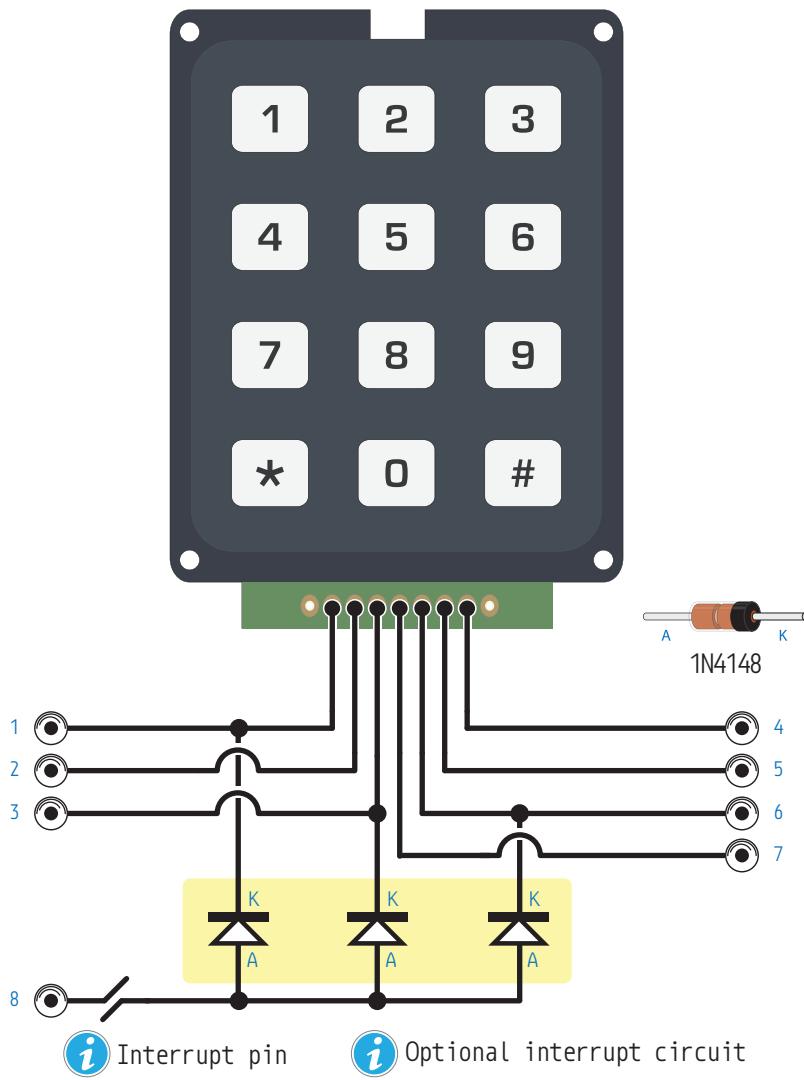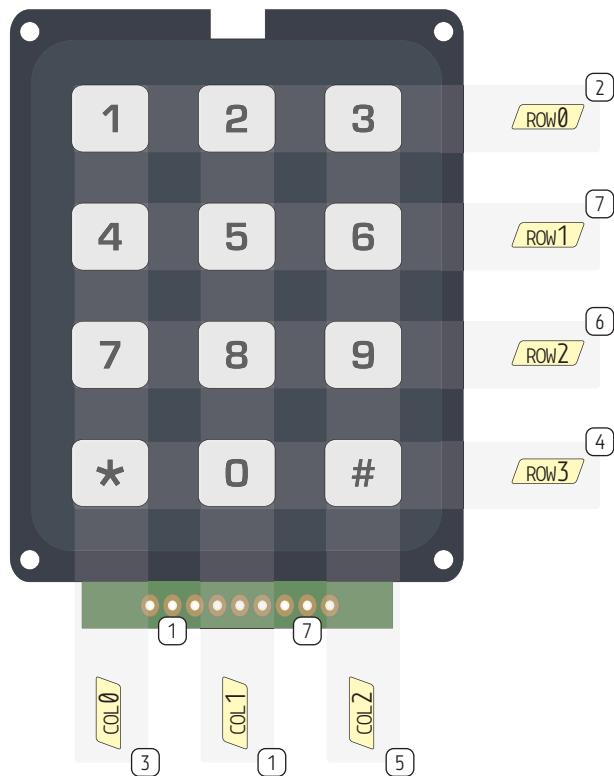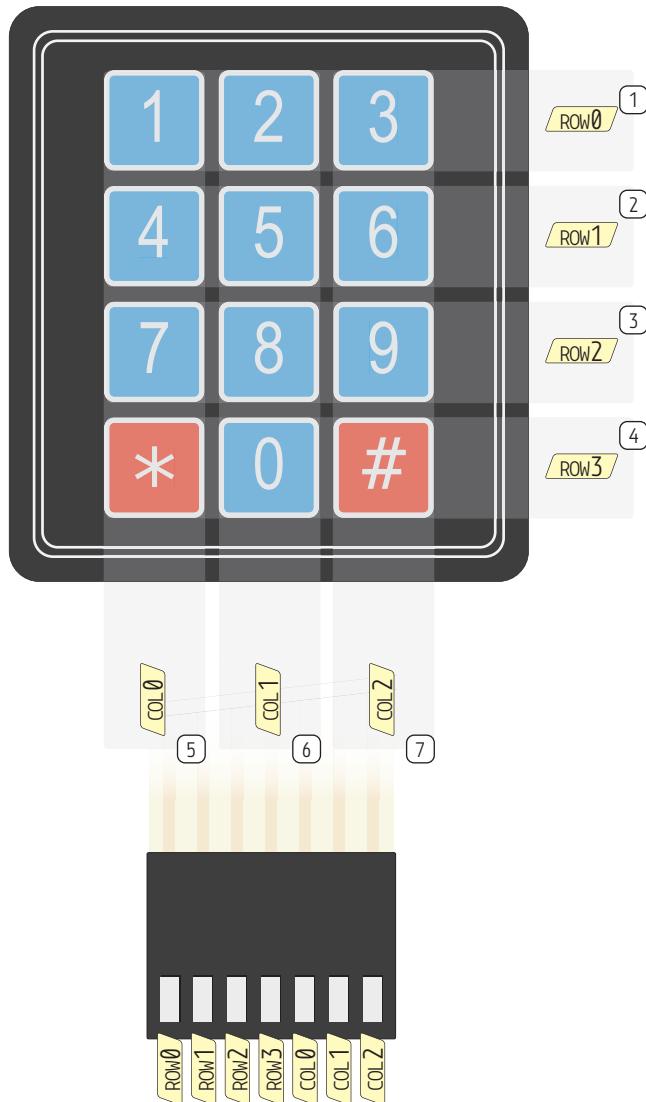
Keypads are ubiquitous in many electronic appliances and are used as input devices. Note that computer and calculator keypads have a different key arrangement compared to telephones, locks or ATMs.

54

Membrane Keypad
Pinout

1	2	3
4	5	6
7	8	9
*	0	#

ROW0 1
ROW1 2
ROW2 3
ROW3 4

COL0 COL1 COL2
5   6   7

ROW0 ROW1 ROW2 ROW3 COL0 COL1 COL2

54
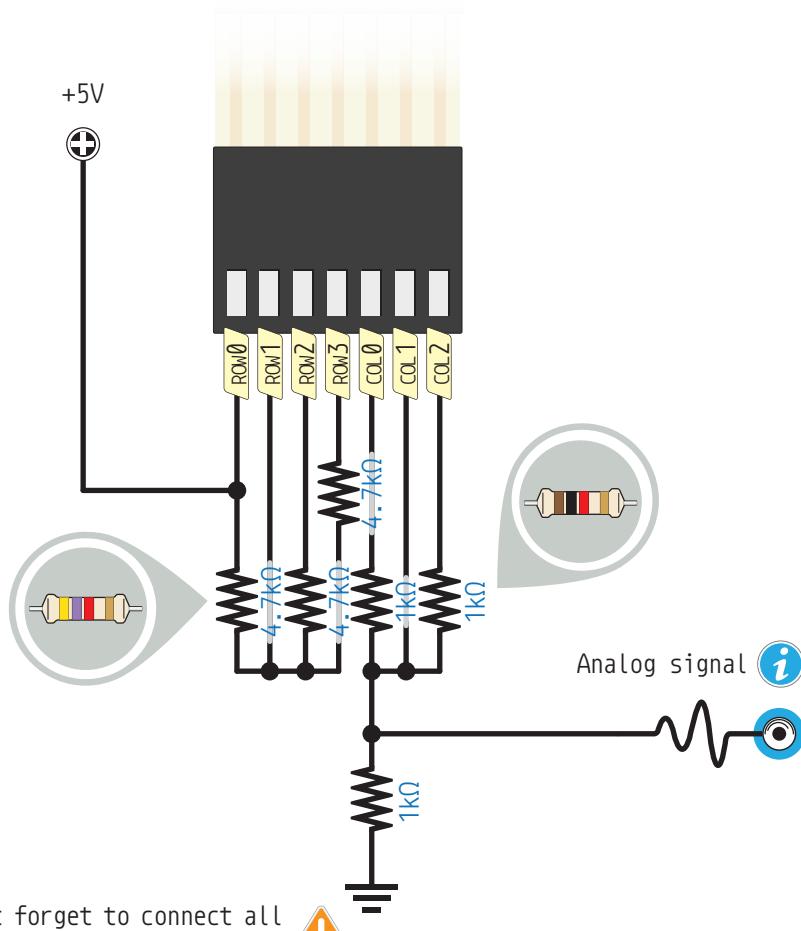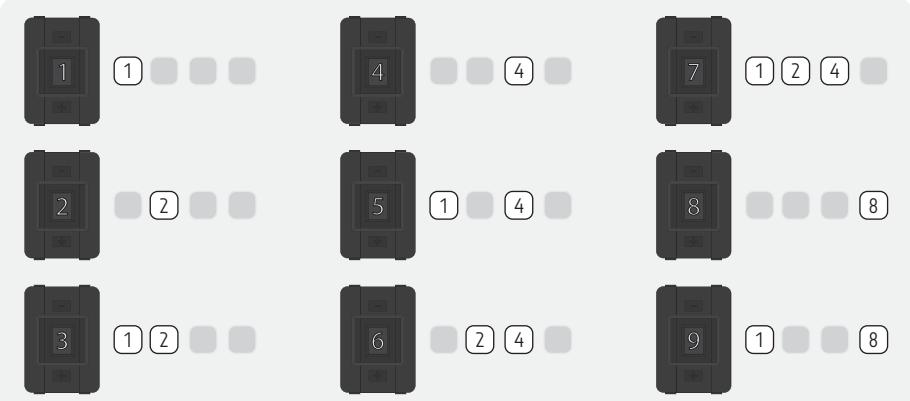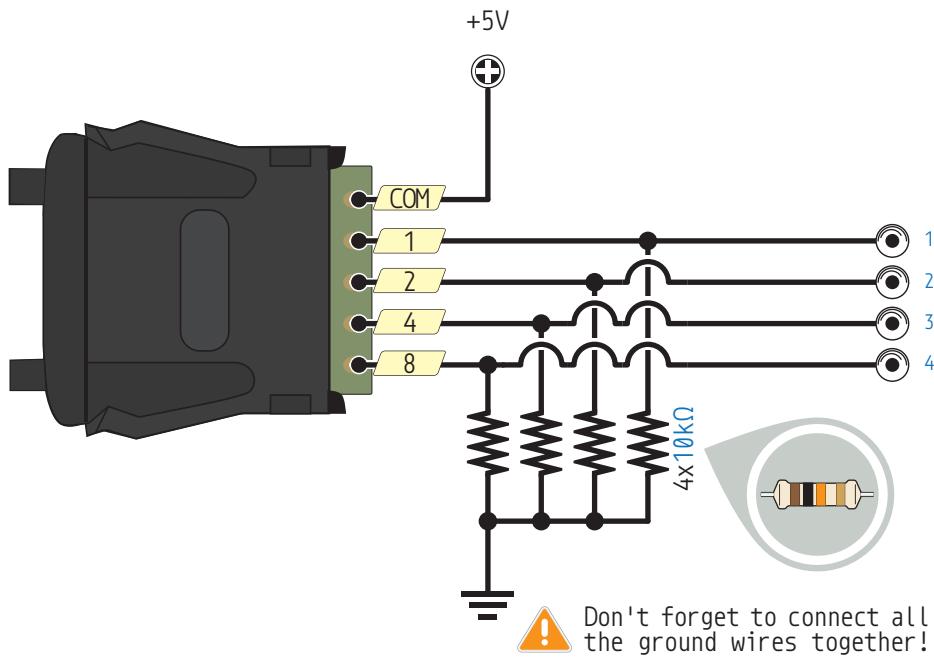
Keypad With 1 Analog Pin
Basic Connections

+5V

ROW0 ROW1 ROW2 ROW3 COL0 COL1 COL2

4.7kΩ

4.7kΩ 4.7kΩ 4.7kΩ 1kΩ 1kΩ

Analog signal

1kΩ

Don't forget to connect all
the ground wires together!

55
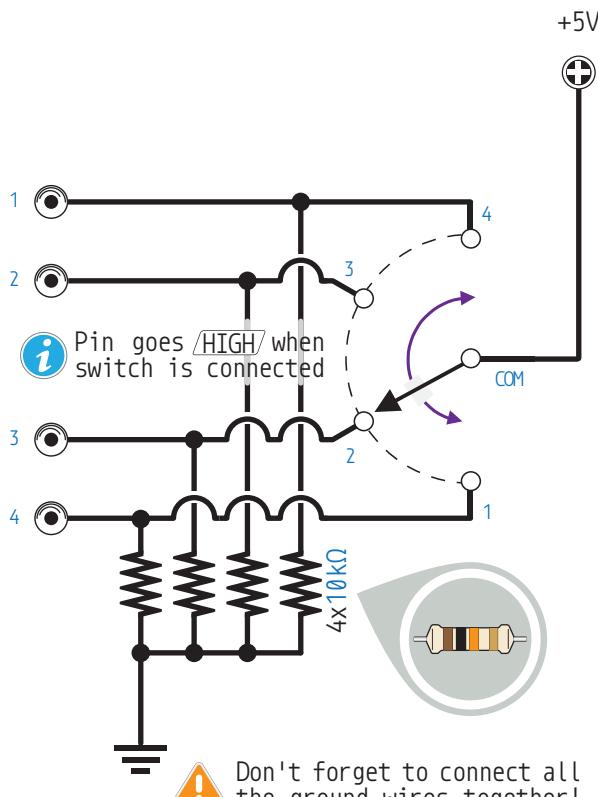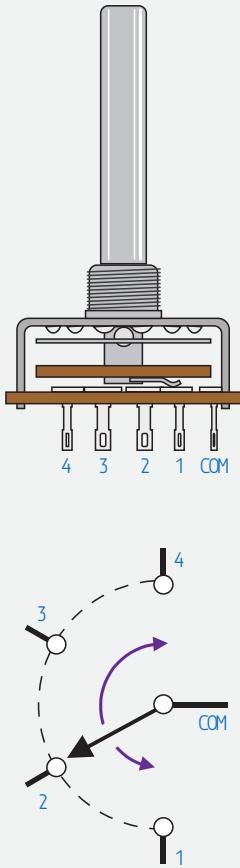
Thumbwheel Switch
Basic Connections

+5V

COM
1
2
4
8

1
2
3
4

4x10kΩ

⚠ Don't forget to connect all the ground wires together!

1	1				4			4		7	1	2	4	
2		2			5	1		4		8				8
3	1	2			6		2	4		9	1			8

56

Rotary Switch
Basic Connections

+5V

1
2
3
4
COM

Pin goes HIGH when switch is connected

4x10kΩ

Don't forget to connect all the ground wires together!

4 3 2 1 COM

4
3
2
COM
1
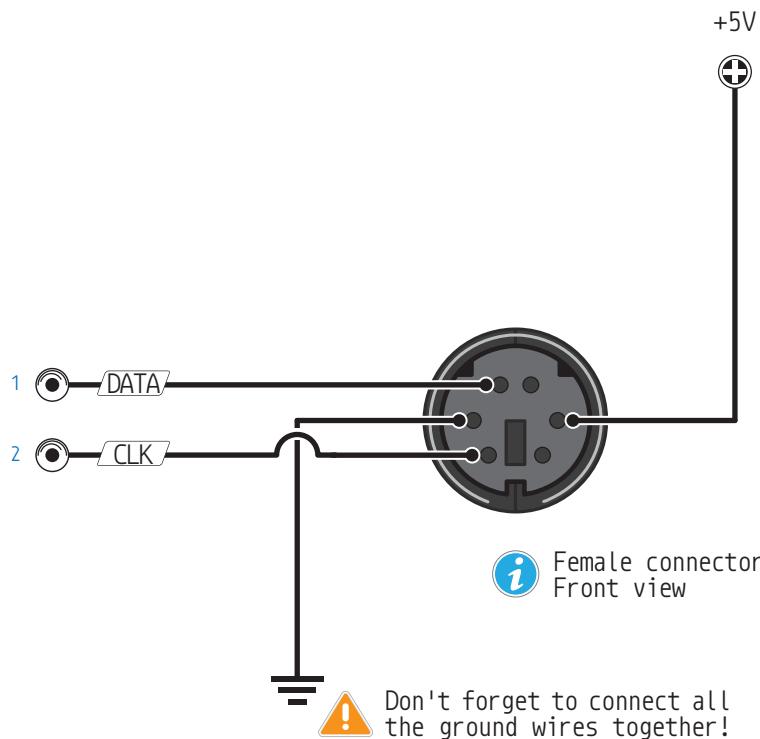
Rotary switches are switches that have fixed angular positions that click in place when the connection is established by rotating the shaft. You could build this circuit using just one analog pin as in the **Multiple Pushbuttons** sheet by replacing the pushbuttons in that circuit with a rotary switch.

PS/2 Keyboard
Basic Connections

+5V

1 DATA

2 CLK

Female connector
Front view

Don't forget to connect all
the ground wires together!
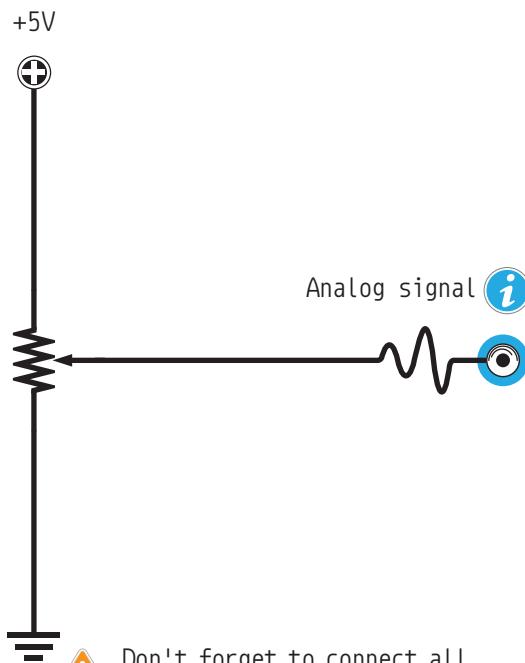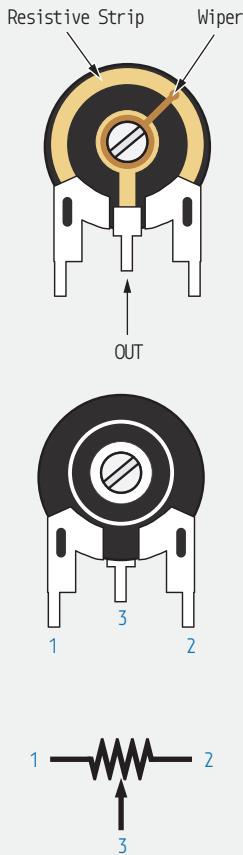
PS/2 is a simple synchronous serial protocol that uses only two wires for communication. Due to its simplicity, PS/2 keyboards are widely used with simple microcontroller boards. PS/2 keyboards can send the equivalent ASCII value of the key that has been pressed.

58

Trimmer
Basic Connections

Resistive Strip   Wiper

OUT

3
1   2

1 —WWW— 2

3

+5V

Analog signal (i)

Don't forget to connect all
the ground wires together!
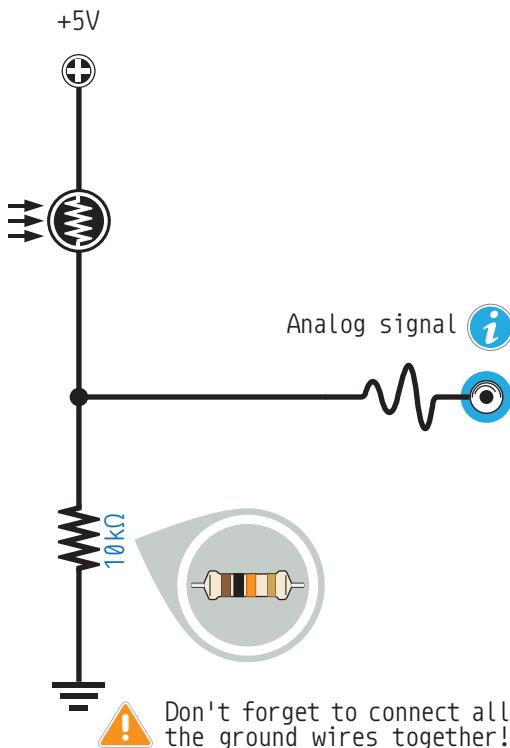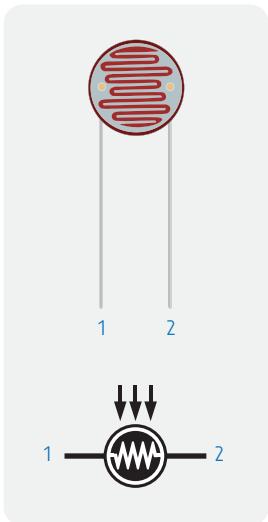
Trimmers are manually-adjustable, variable resistors with three terminals. Two
terminals are connected to a resistive element and the third terminal is
connected to an adjustable wiper. In this circuit, the position of the wiper
determines the output voltage.

59

Photoresistor (LDR)
Basic Connections

+5V

1   2

1 —WW— 2

Analog signal ⓘ

10kΩ

⚠ Don't forget to connect all
the ground wires together!
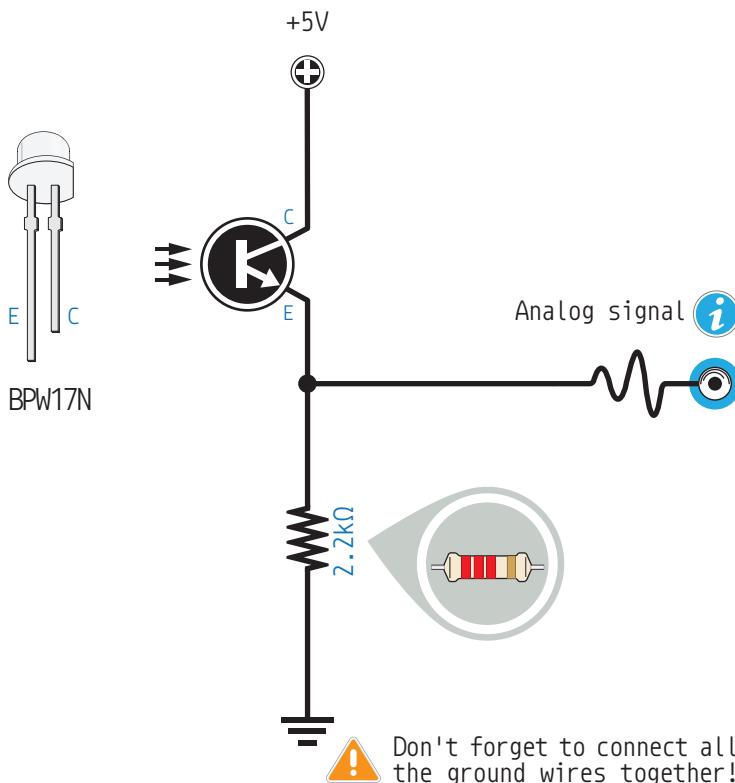
Photoresistors or photocells are light-controlled variable resistors. The
resistance of a photoresistor decreases with increasing incident light intensity.
Photoresistors can be applied in light-sensitive detector circuits and
light-activated switching circuits.

60

Phototransistor
Basic Connections

+5V

C

E

Analog signal

BPW17N

E   C

2.2kΩ

Don't forget to connect all
the ground wires together!
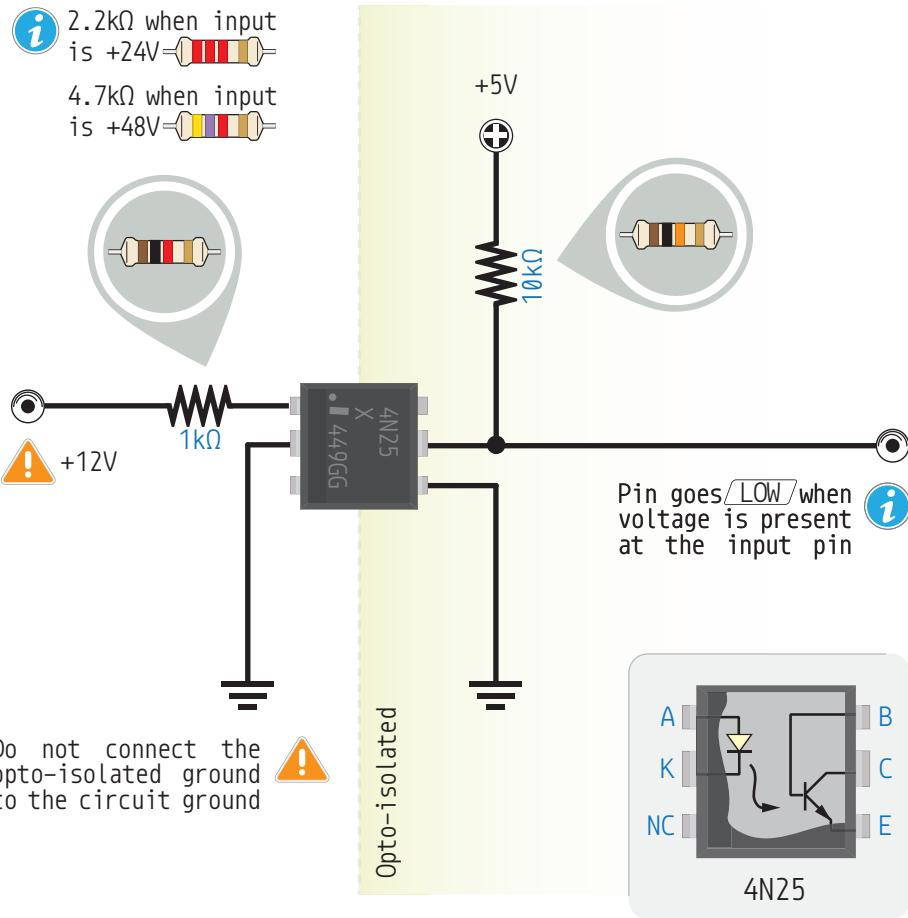
Phototransistors are light-sensitive transistors. Light reaches the   the
base-collector junction, where electrons are generated, and the current is
amplified by the current gain. Phototransistors are faster than photoresistors
and slower than photodiodes, but they are less sensitive to temperature.

61

Opto-Isolated DC Input
Using the 4N25 Optocoupler

i 2.2kΩ when input is +24V

4.7kΩ when input is +48V

1kΩ

⚠ +12V

+5V

10kΩ

4N25
X
4496G

Pin goes /LOW/ when voltage is present at the input pin *i*

Do not connect the opto-isolated ground to the circuit ground ⚠

Opto-isolated

A   B
K   C
NC   E

4N25

62
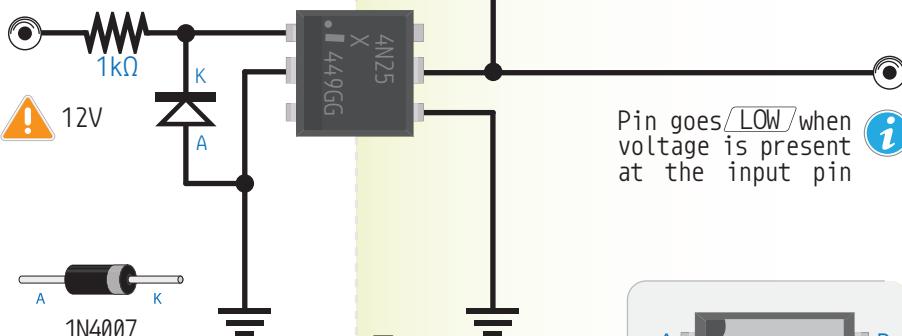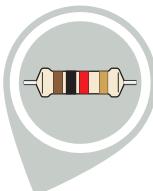
Opto-Isolated AC Input
Using the 4N25 Optocoupler

2.2kΩ when input is 24V

4.7kΩ when input is 48V

+5V

10kΩ

4N25
X
4496G

1kΩ

K

A

⚠ 12V

A   K

1N4007

Do not connect the opto-isolated ground to the circuit ground ⚠

Opto-isolated

Pin goes LOW when voltage is present at the input pin ⓘ

A   B

K   C

NC   E

4N25

63
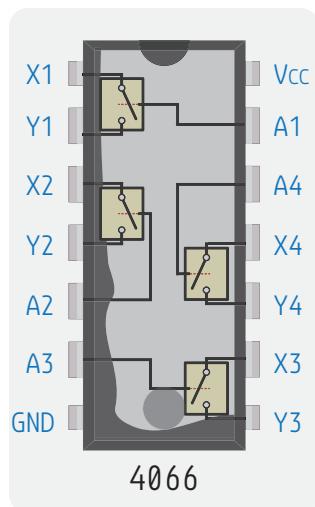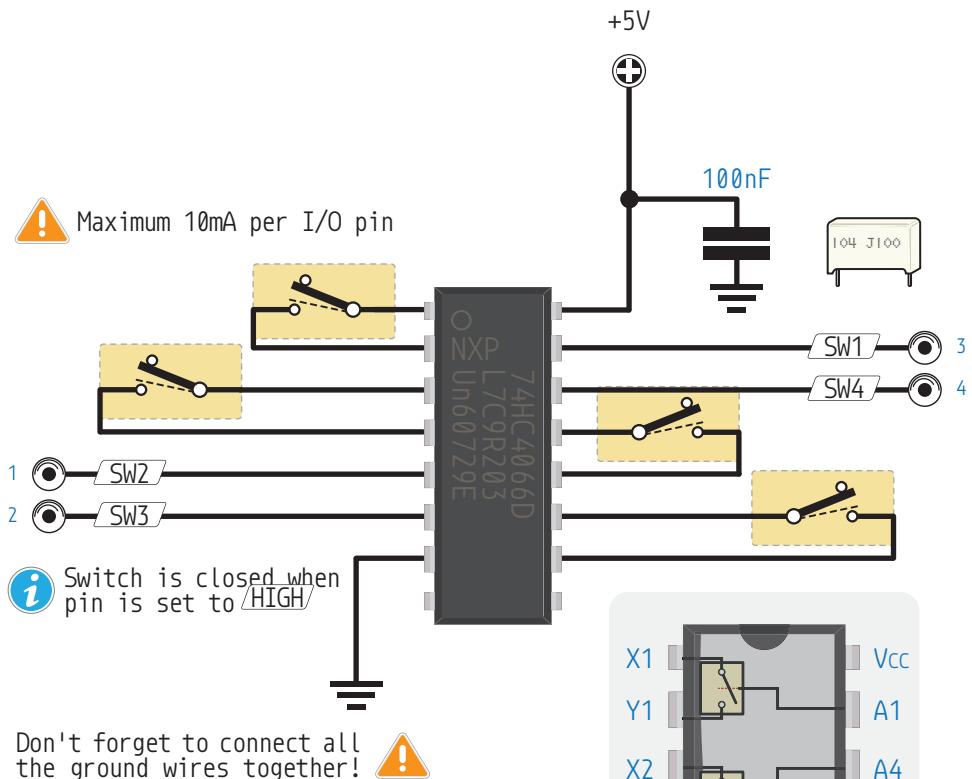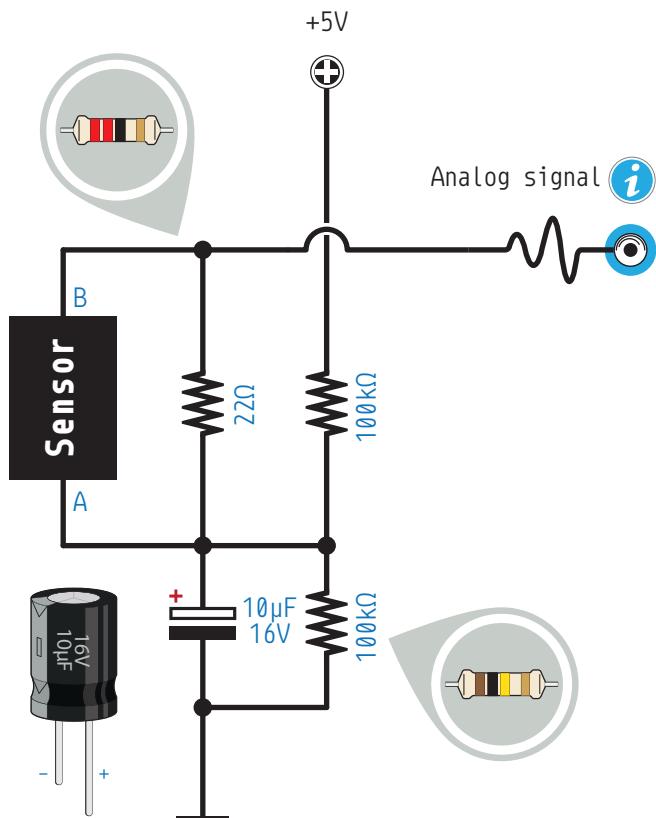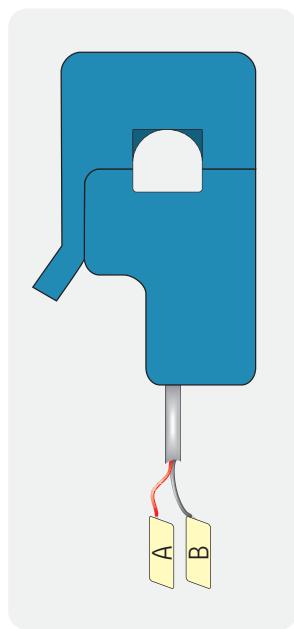
SPST CMOS Analog Switch
Using the 4066 Quad Bilateral Switch

+5V

100nF

⚠ Maximum 10mA per I/O pin

I04 J100

NXP 74HC4066D L7C9R203 Un60729E

SW1 — 3

SW4 — 4

1 — SW2

2 — SW3

ℹ Switch is closed when pin is set to HIGH

Don't forget to connect all the ground wires together! ⚠

	4066	
X1		Vcc
Y1		A1
X2		A4
Y2		X4
A2		Y4
A3		X3
GND		Y3

4066

64

AC Current Sensor
Basic Connections

+5V

Analog signal

Sensor

B

A

22Ω

100kΩ

100kΩ

10µF
16V

16V
10µF

− +

A
B

Don't forget to connect all
the ground wires together!
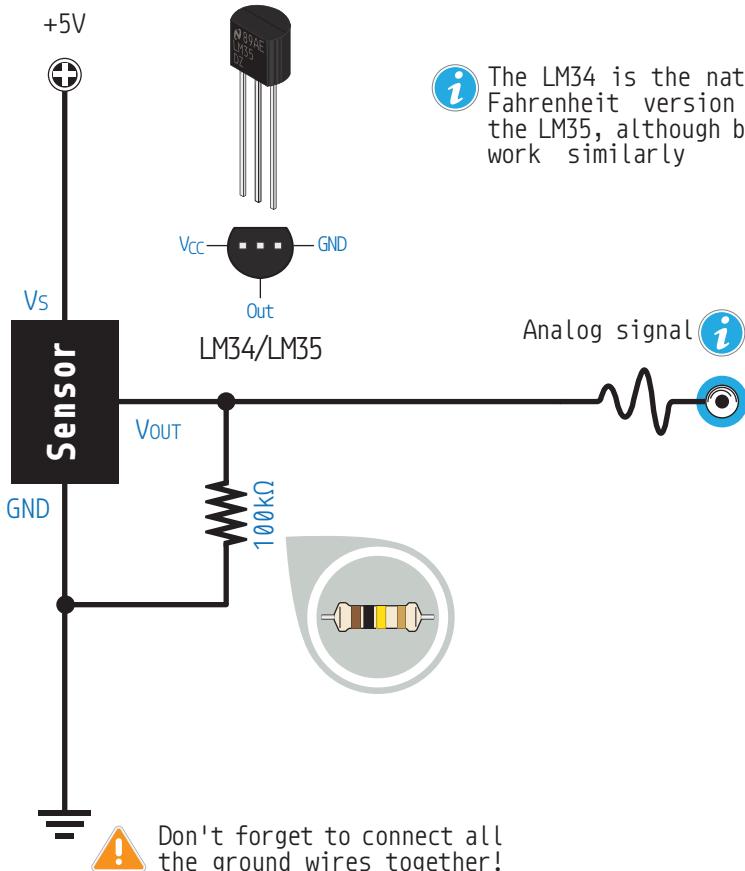
These non-invasive current sensing probes are an affordable solution for measu-
ring high AC current. They are also called CT (current transformer) sensors
because they act like current transformers, delivering a fraction of the current
measured through magnetic induction.

65

LM34/LM35 Temperature Sensor
Basic Connections

+5V

i The LM34 is the native Fahrenheit version of the LM35, although both work similarly

Vcc — GND

Out

LM34/LM35

Vs

Sensor

VOUT

GND

100kΩ

Analog signal **i**

Don't forget to connect all the ground wires together!
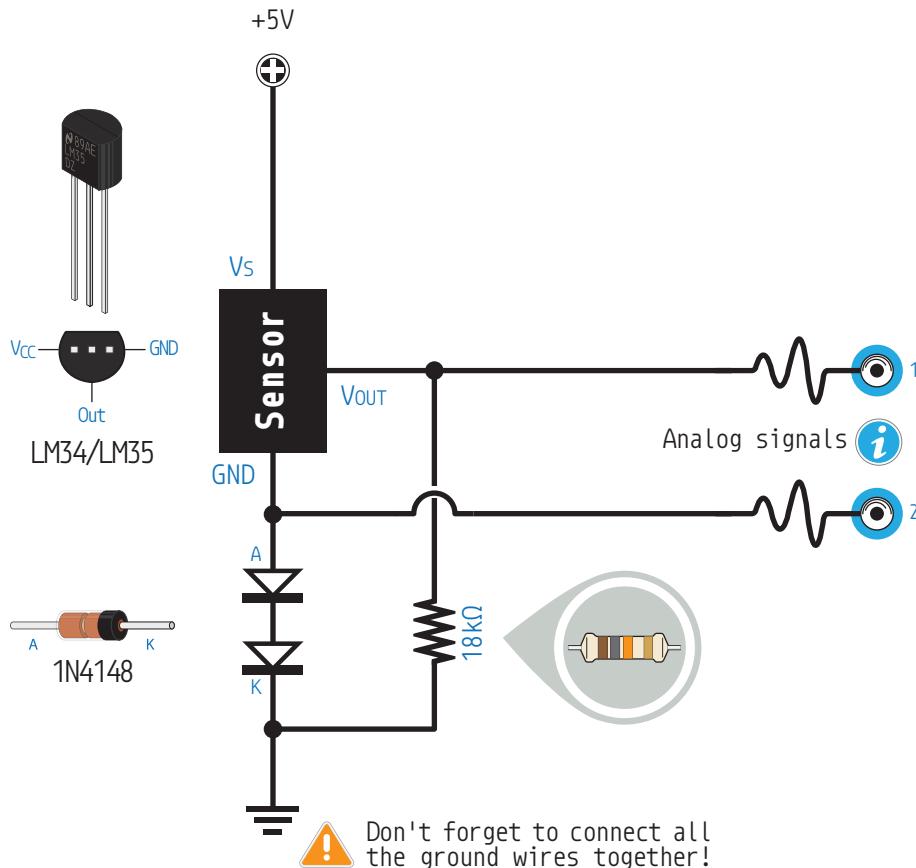
The LM35 is an analog, precision temperature sensor. This circuit allows for a measuring range of 2°C to +150°C (35.6°F to +302°F) with a temperature accuracy of ±0.5°C (0.9°F). The output of the sensor is linear with respect to the measured temperature, increasing its output voltage by 10mV per degree Celsius.

66

LM34/LM35 Temperature Sensor
Full Range

+5V

V_S

Sensor

V_{OUT}

GND

V_{CC} — GND

Out

LM34/LM35

A

K

1N4148

A

1

Analog signals *i*

2

18kΩ

Don't forget to connect all
the ground wires together!
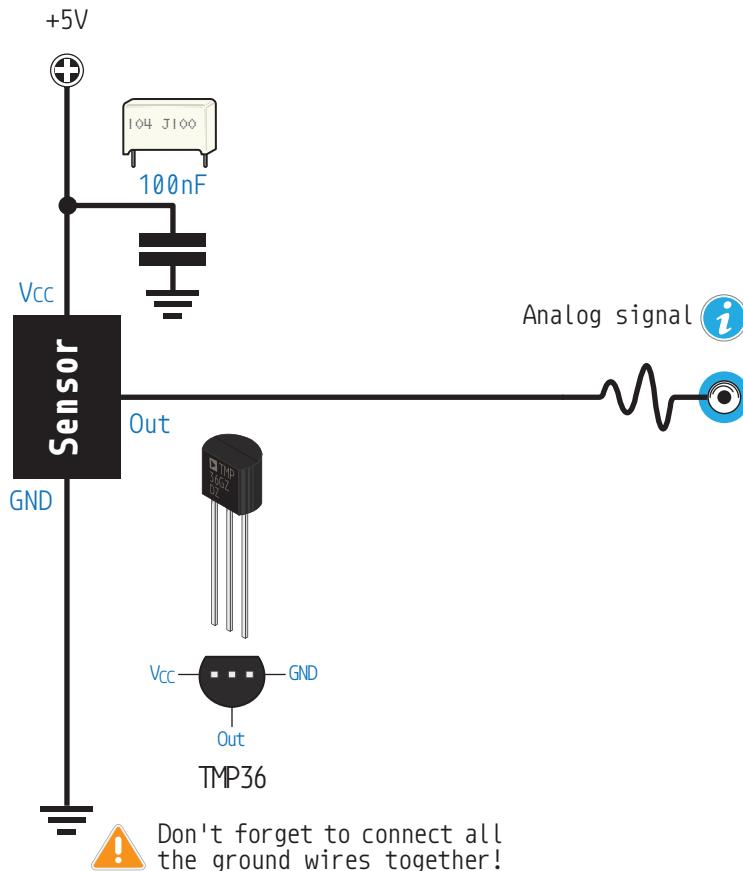
This circuit allows the LM35 to achieve its full potential, allowing for a
temperature measuring range of −55°C to +150°C (−67°F to +302°F). The voltage
is measured between both analog signal outputs, so you need to read the values
with your microcontroller and obtain the absolute value of the difference.

67

TMP36 Temperature Sensor
Basic Connections

+5V

104 J100

100nF

Vcc

Sensor

Out

GND

Analog signal *i*

TMP
366Z
D2

Vcc ————— GND

Out

TMP36

⚠ Don't forget to connect all
the ground wires together!
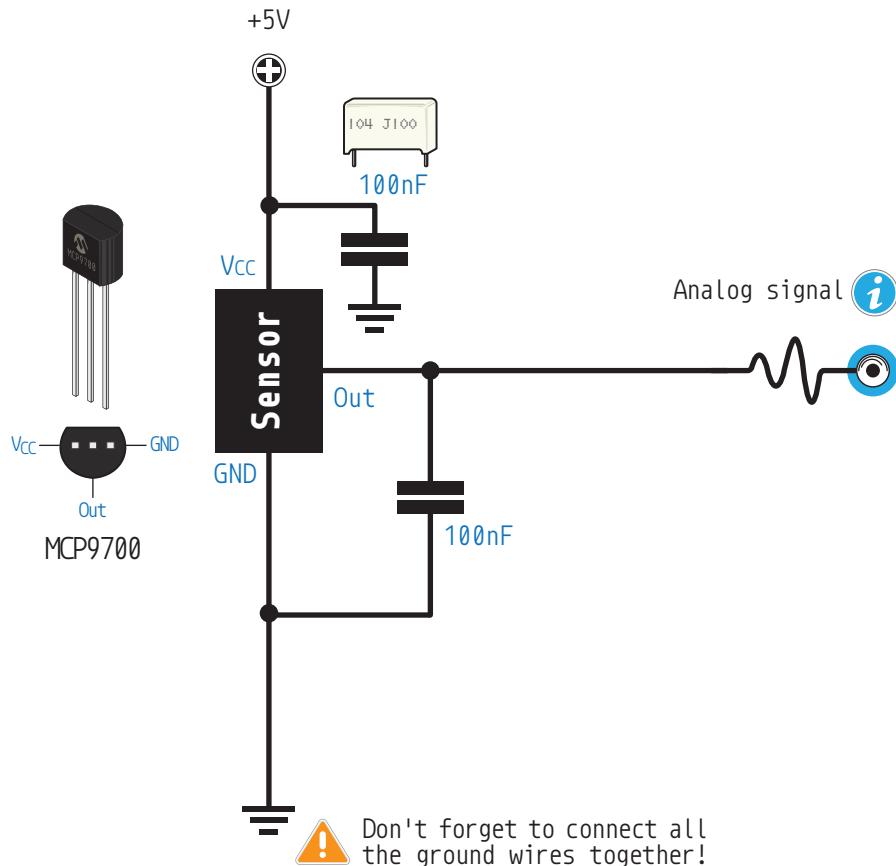
💡 The TMP36 is an analog temperature sensor with a measuring range of −40°C to
+125°C (−40°F to +257°F). It has a temperature accuracy of ±2°C and it is very
linear.

68

MCP9700 Temperature Sensor
Basic Connections

+5V

104 J100

100nF

Vcc

Sensor

Out

GND

100nF

Analog signal ⓘ

Vcc — GND

Out

MCP9700

⚠ Don't forget to connect all the ground wires together!
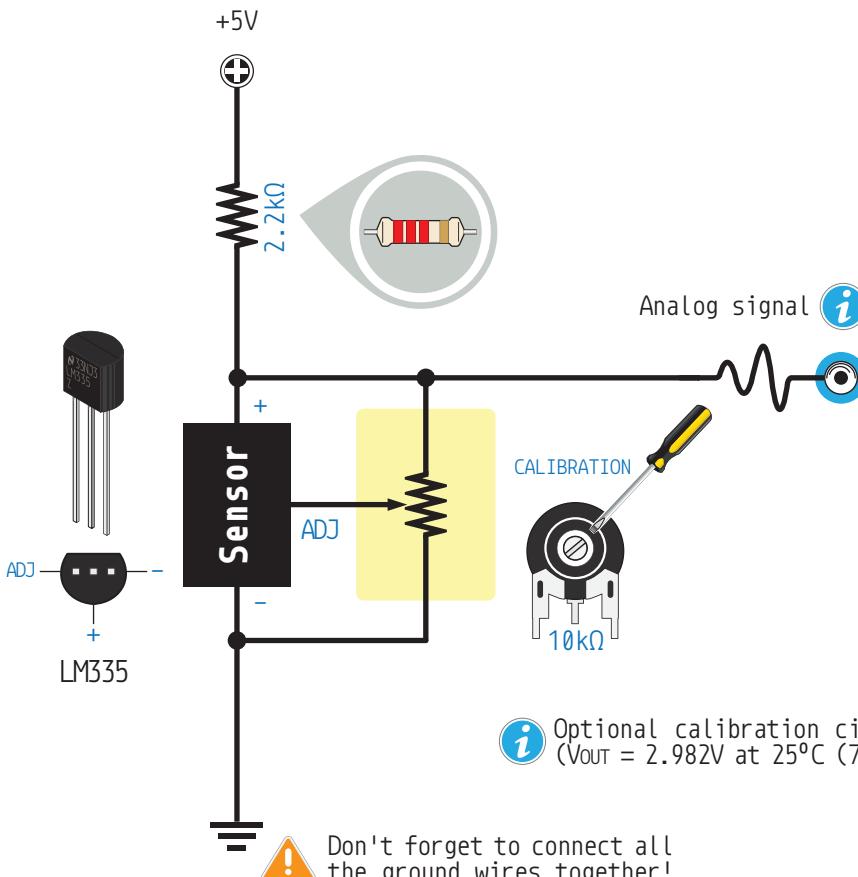
💡 The MCP9700 is an analog temperature sensor with a measuring range of −40°C to +125°C (−40°F to +257°F). It has a temperature accuracy of ±2°C and it is very linear.

69

LM335 Temperature Sensor
Basic Connections

+5V

2.2kΩ

Analog signal (i)

Sensor

+

ADJ

−

CALIBRATION

ADJ −

+

LM335

10kΩ

(i) Optional calibration circuit
(V_{OUT} = 2.982V at 25°C (77°F))

⚠ Don't forget to connect all
the ground wires together!
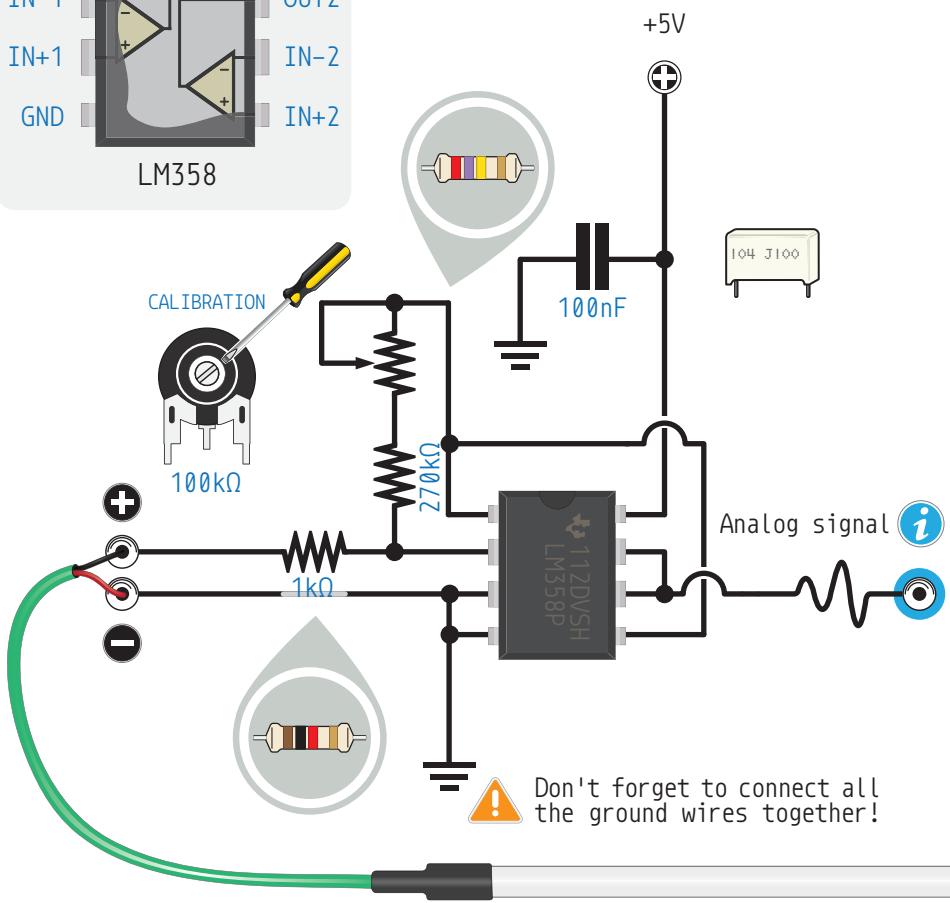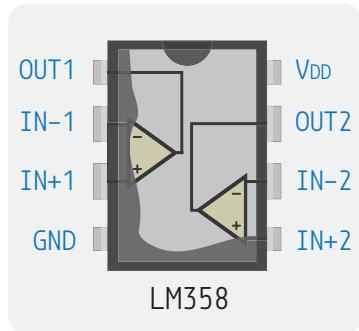
💡 The LM335 is a digital, linear, precision temperature sensor. It has a tempera-
ture measuring range of −55°C to +150°C (−67°F to +302°F) with an accuracy of
1°C (1.8°F). The LM335 measures temperature in Kelvin, so you will need to
subtract 273 from your measurement to obtain the temperature in Celsius.

Thermocouple
Using the LM358 Op-Amp

OUT1   V_{DD}

IN−1   OUT2

IN+1   IN−2

GND   IN+2

LM358

+5V

100nF

104 J100

CALIBRATION

100kΩ

270kΩ

1kΩ

112DVSH
LM358P

Analog signal

Don't forget to connect all
the ground wires together!
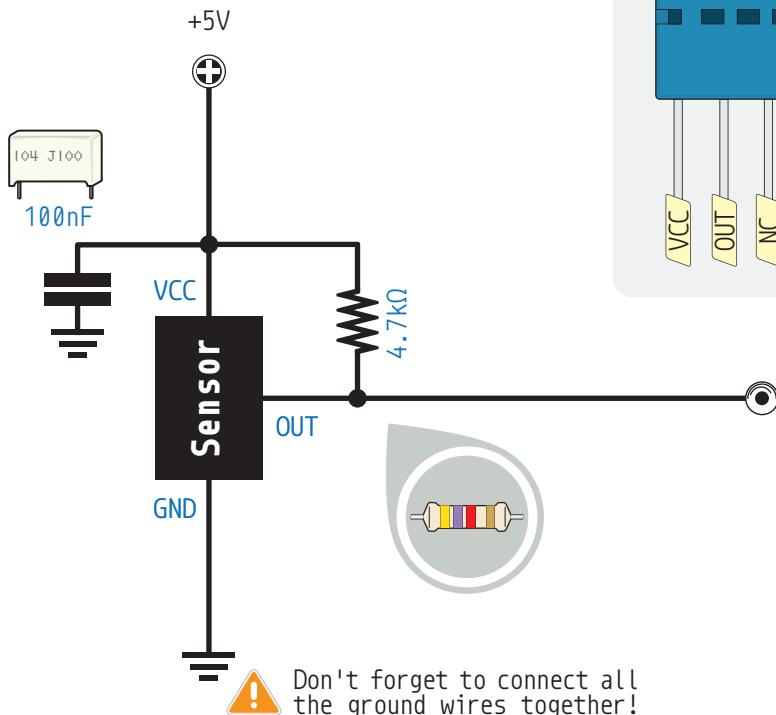
Check wiring color codes online

DHT11 Temp. & Humidity Sensor
Basic Connections

+5V

100nF

VCC

4.7kΩ

Sensor

OUT

GND

VCC OUT NC GND

⚠️ Don't forget to connect all the ground wires together!

💡 The DHT11 is a digital, low cost, medium precision humidity and temperature sensor. Its measuring ranges are 20 to 90% (±5%) for relative humidity and 0°C to 50°C (±2°C) (32°F to 122°F (±3.6°F)) for temperature.
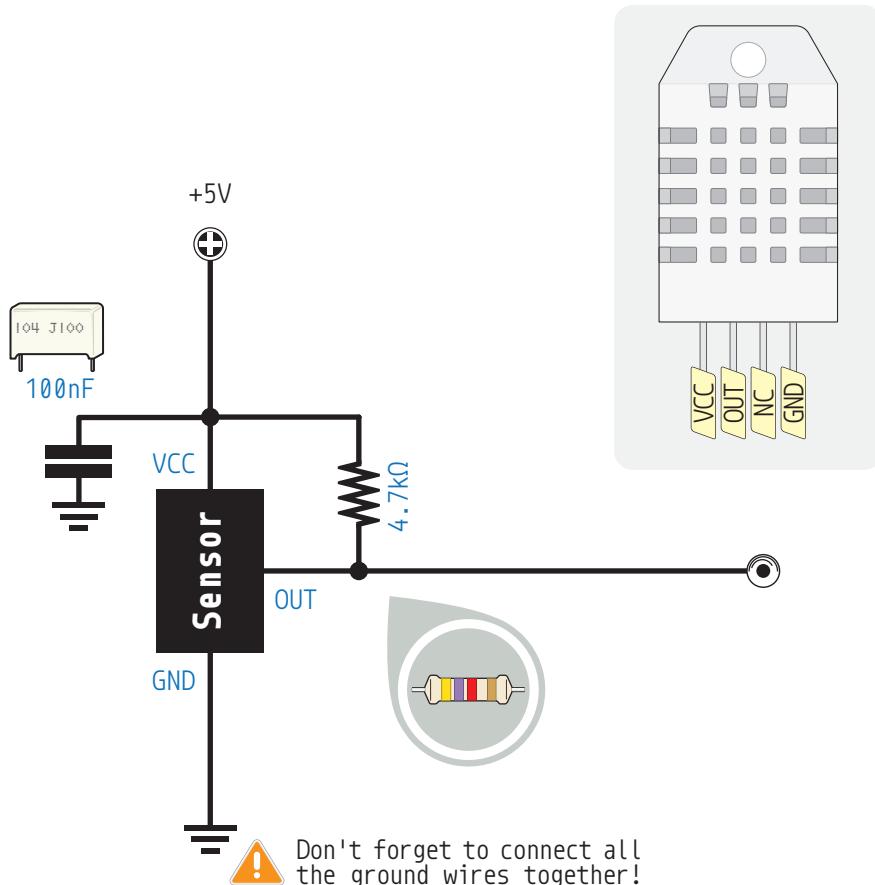
72

DHT22 Temp. & Humidity Sensor
Basic Connections

+5V

100nF

VCC

4.7kΩ

Sensor

OUT

GND

⚠️ Don't forget to connect all the ground wires together!
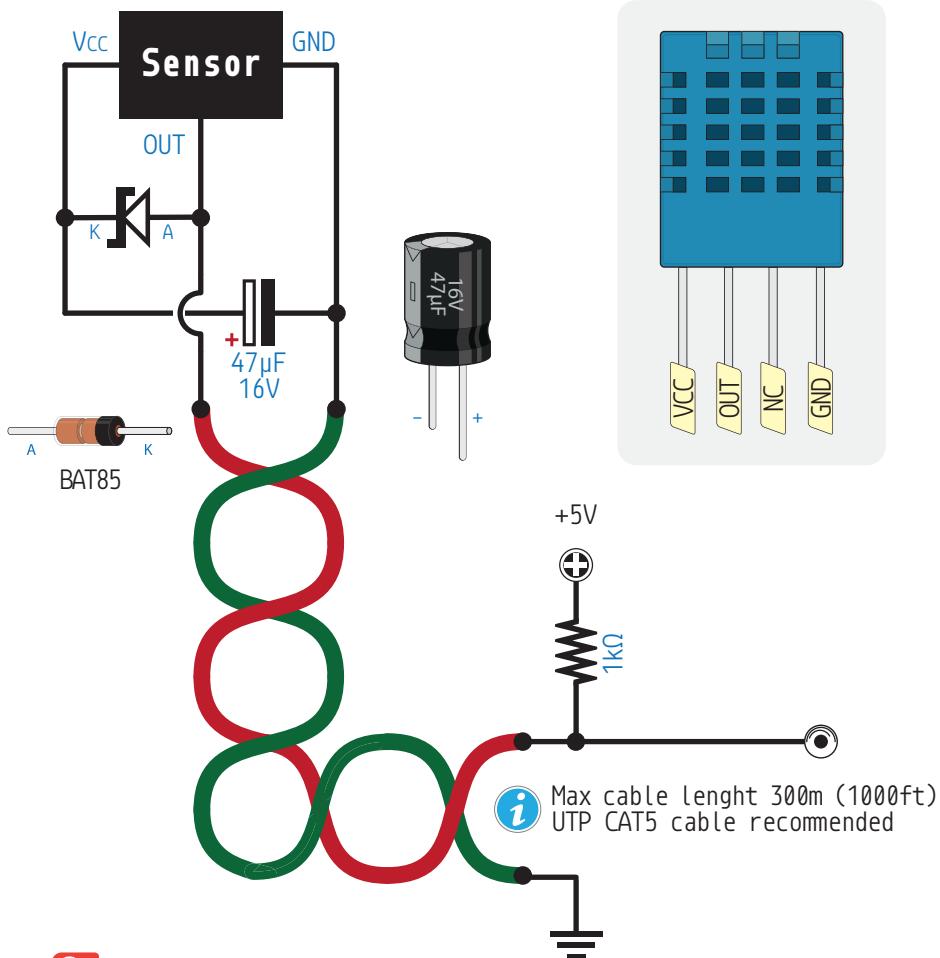
💡 The DHT22 (also called AM2302) is a digital temperature and humidity sensor very similar to the DHT11, except it offers higher-precision readings. Its measuring ranges are 0 to 90% (±2%) for relative humidity and –40°C to 80°C (±0.5°C) (–40°F to 176°F (±0.9°F)) for temperature.

73

DHT11/DHT22 2-Wire Connection
Basic Connections

Sensor

Vcc GND

OUT

K   A

+ 47µF 16V

16V 47µF

– +

BAT85

A   K

VCC OUT NC GND

+5V

1kΩ

Max cable lenght 300m (1000ft)
UTP CAT5 cable recommended
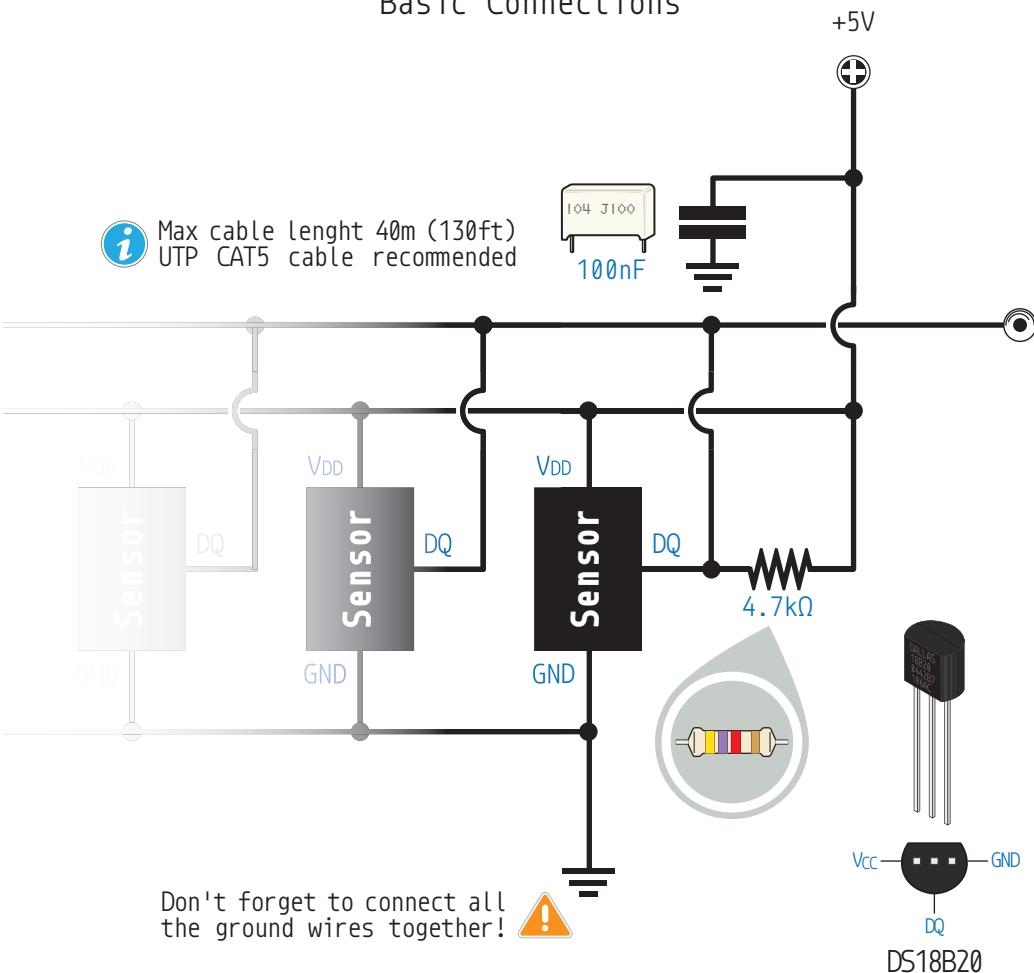
This 2-wire connection circuit allows for reliable measurements over long distances. Twisted pair cables like UTP CAT5, used in computer networks such as Ethernet, are affordable and ubiquitous.

DS18B20 Temperature Sensor
Basic Connections

+5V

Max cable lenght 40m (130ft)
UTP CAT5 cable recommended

104 J100

100nF

V$_{DD}$

Sensor

DQ

V$_{DD}$

Sensor

DQ

V$_{DD}$

Sensor

DQ

GND

GND

4.7kΩ

DALLAS
18B20
+2537
1621C

V$_{CC}$ — GND

DQ

DS18B20

Don't forget to connect all
the ground wires together! ⚠️
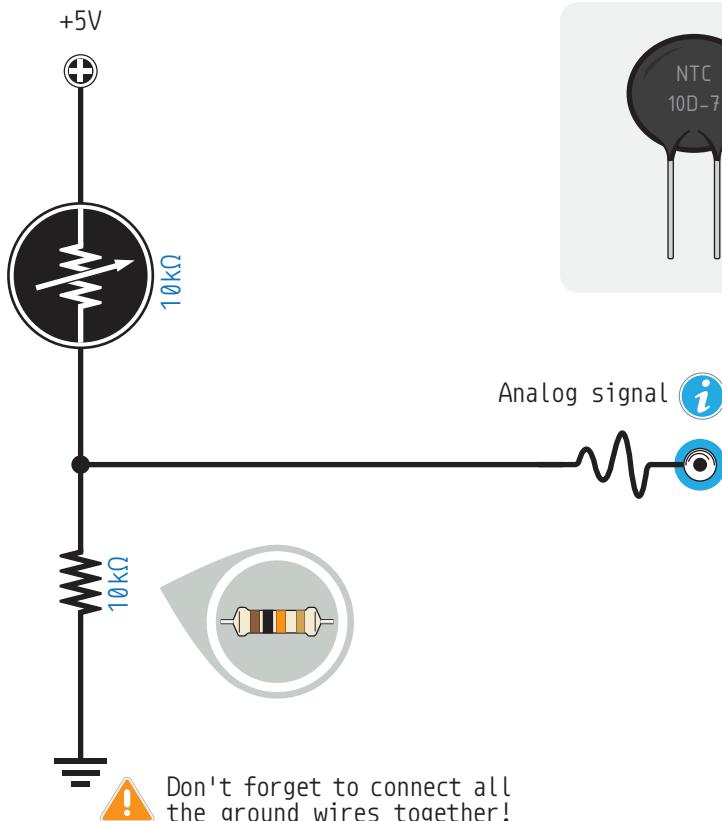
💡 The DS18B20 is a digital, precision temperature sensor with a measuring range
of -55°C to +150°C (±0.5°C) (-67°F to +257°F (±0.9°F)). Its 1-wire interface
requires only one port pin for communication, providing the temperature value
with just a few lines of code and allowing multiple sensors to run in parallel.

NTC Thermistor
Basic Connections

+5V

10kΩ

NTC
10D-7

Analog signal

10kΩ

Don't forget to connect all
the ground wires together!
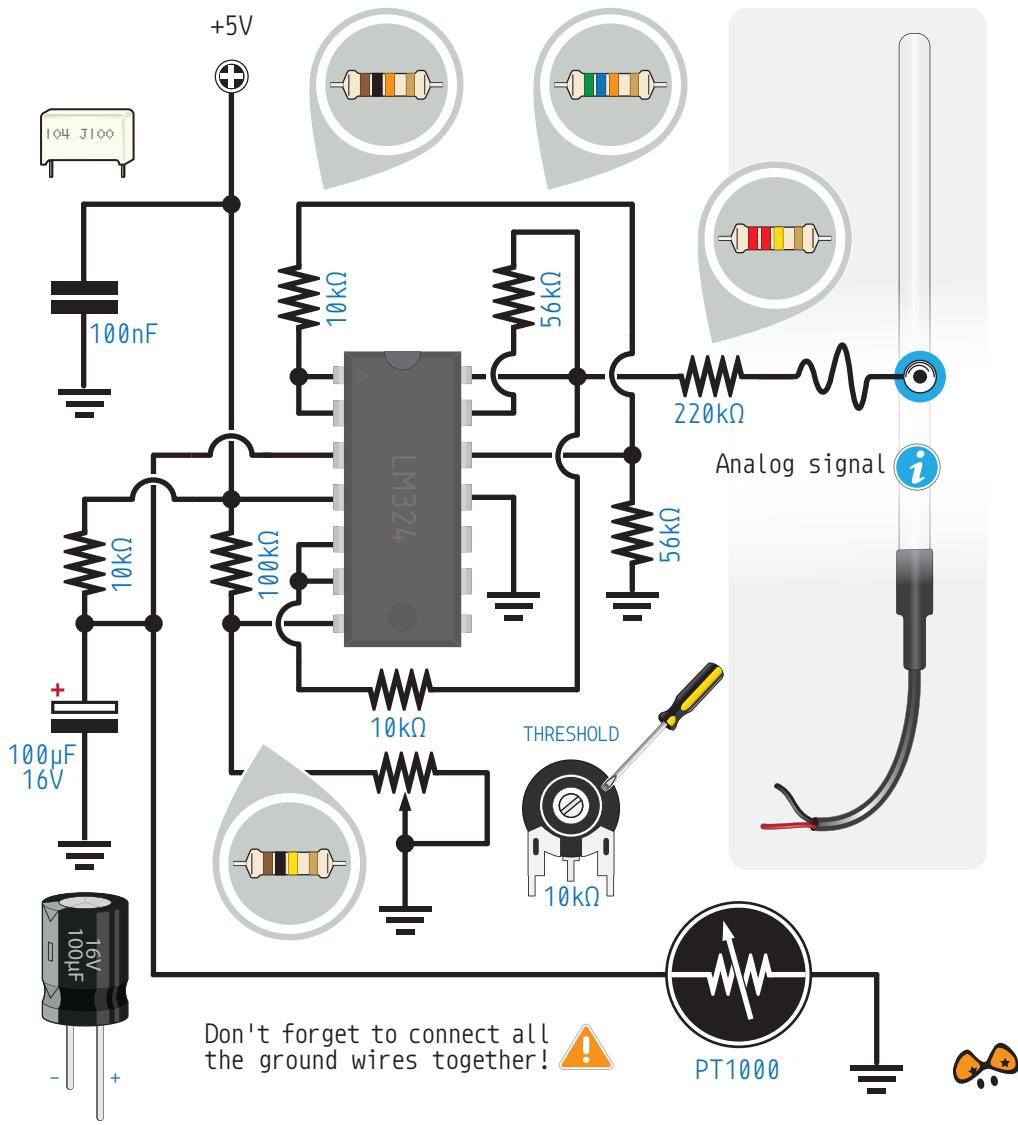
Thermistors (thermally-sensitive resistors) are a type of resistor whose resistance is dependent on temperature. Their temperature range is typically -55°C to 200°C (-67°F to 392°F). Thermistors are affordable, sensitive but not very linear.

76
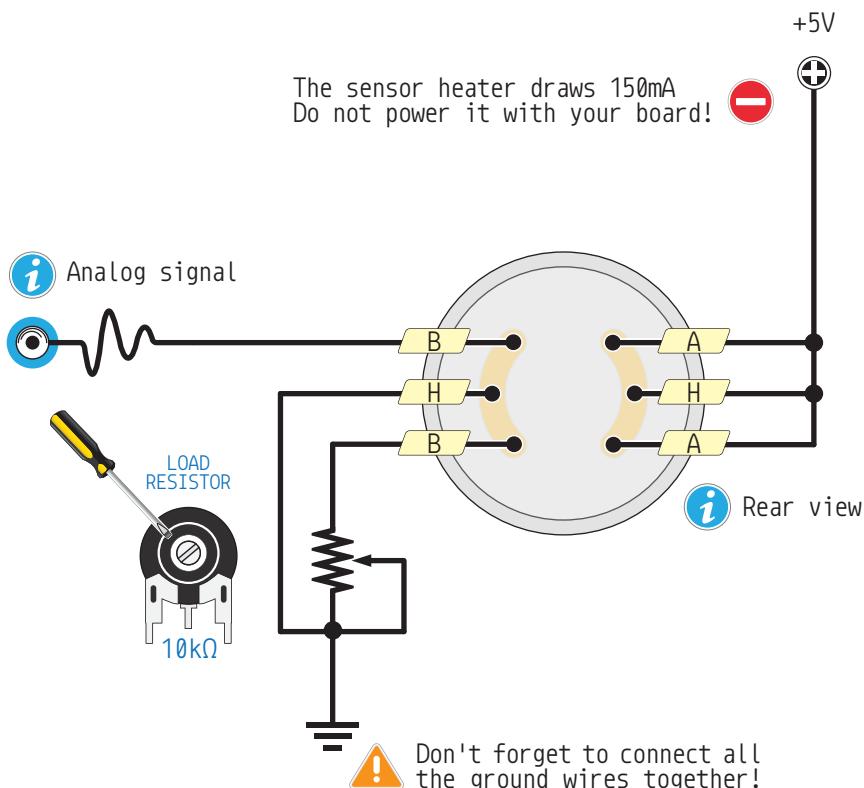
RTD Temperature Sensor
Using a PT1000 Sensor

+5V

104 J100

100nF

10kΩ

56kΩ

220kΩ

56kΩ

LM324

10kΩ

100kΩ

10kΩ

Analog signal

10kΩ

100µF
16V

16V
100µF

THRESHOLD

10kΩ

PT1000

Don't forget to connect all
the ground wires together! ⚠️

- +

77

Gas Sensor
Using an MQ Series Sensor

+5V

The sensor heater draws 150mA
Do not power it with your board! 🚫

ℹ️ Analog signal

B

A

H

H

B

A

LOAD
RESISTOR

Rear view ℹ️

10kΩ

Don't forget to connect all
the ground wires together!
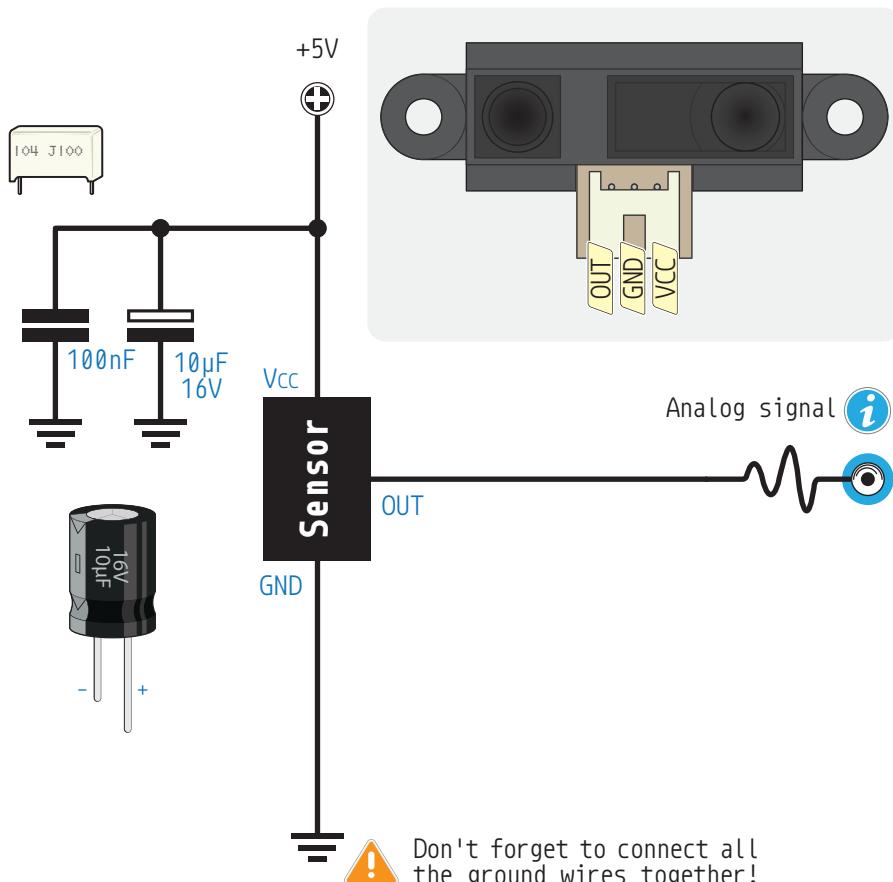
💡 The MQ series of gas sensors use a small heater inside with an electro-chemical
sensor. They are sensitive for a range of gasses at room temperature such as
methane, butane, propane, natural gas, LPG, smoke, alcohol, ethanol, ozone,
hydrogen, benzene, hydrogen sulfide, toluene, acetone, CO2, CO, etc.

78

Sharp GP2Y0A21 Distance Sensor
Basic Connections

+5V

104 J100

100nF

10µF
16V

16V
10µF

− +

Vcc

Sensor

OUT

GND

OUT
GND
VCC

Analog signal

Don't forget to connect all
the ground wires together!
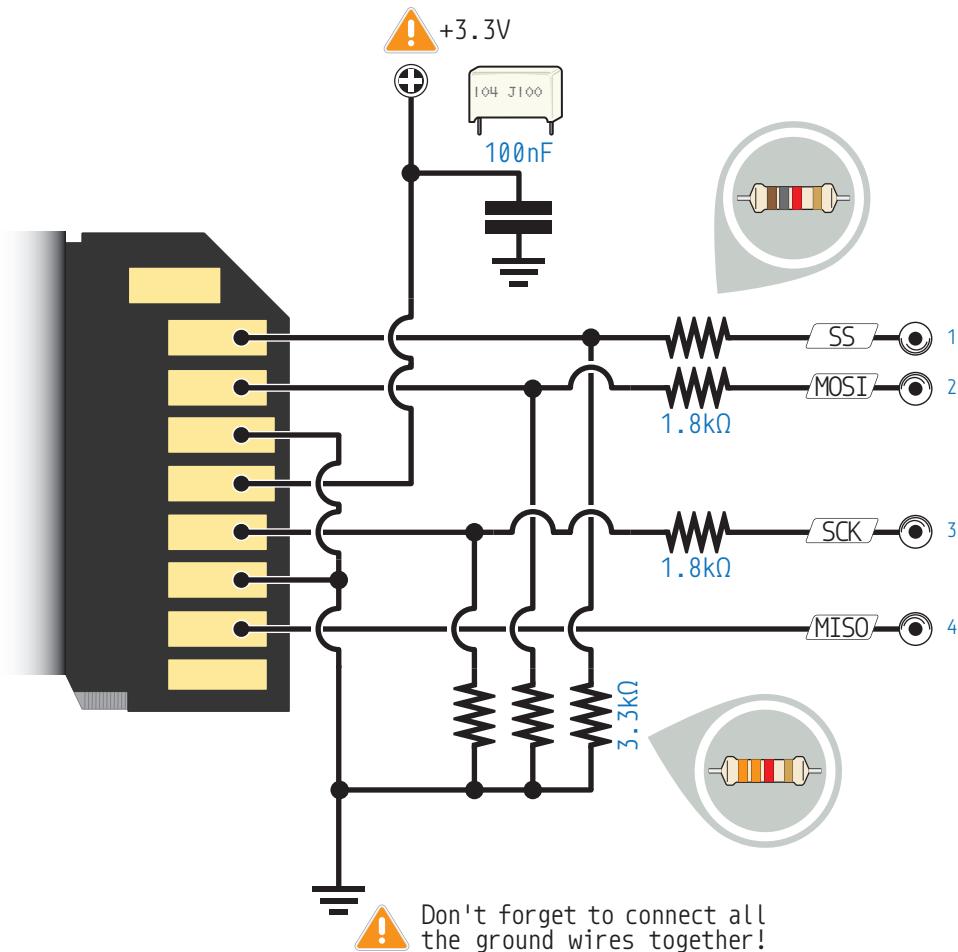
The Sharp GP2Y0A21 distance sensor is a popular choice for many projects that
require accurate distance measurements, it has a measuring range of 10 to 80cm
(4 to 32in). The relationship between the output voltage and the inverse of the
measured distance is nonlinear and needs to be linearized in the code.

79

DIY microSD Card Reader
Basic Connections

⚠ +3.3V

⊕

104 J100

100nF

SS 1

MOSI 2

1.8kΩ

SCK 3

1.8kΩ

MISO 4

3.3kΩ

⚠ Don't forget to connect all
the ground wires together!
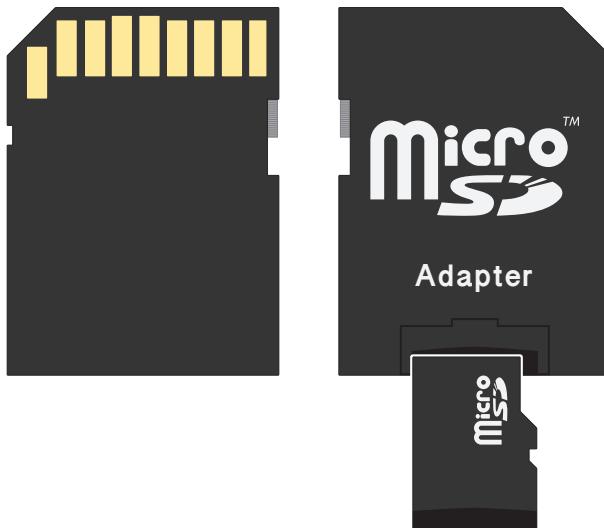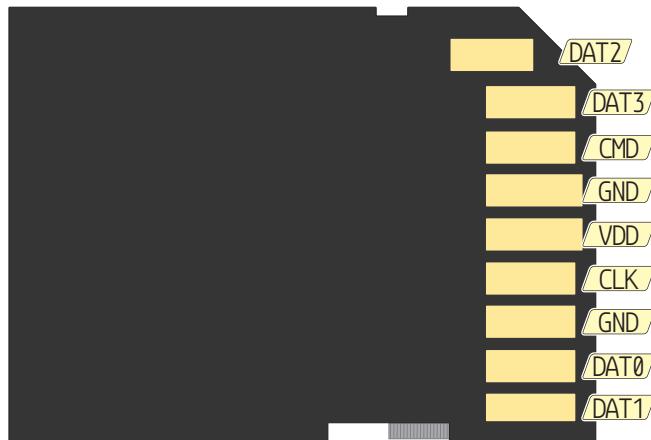
microSD to SD card adapters come bundled with many microSD cards nowadays. You
can build this circuit to convert that adapter into a microSD card reader for
your microcontroller board.

SD Card
Pinout

DAT2
DAT3
CMD
GND
VDD
CLK
GND
DAT0
DAT1

micro **SD**™
Adapter

micro **SD**

80
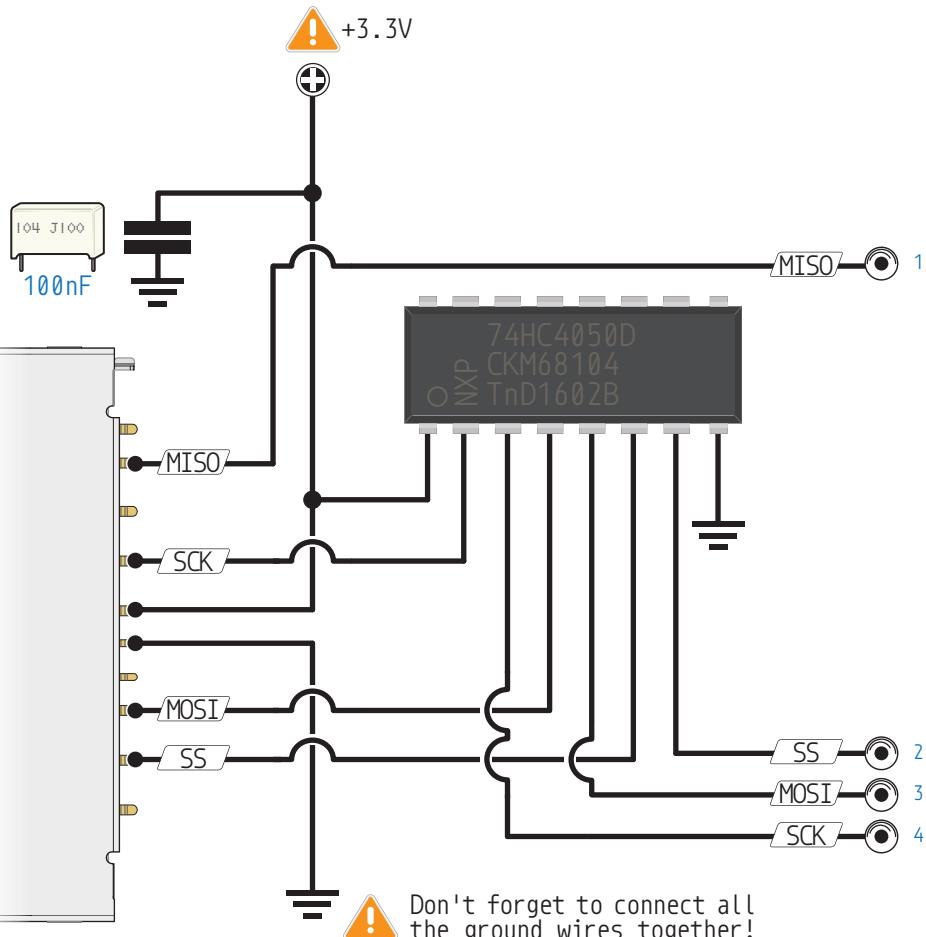
SD Card
Using the 4050 Buffer

⚠️ +3.3V

⊕

104 J100
100nF

74HC4050D
NXP CKM68104
TnD1602B

MISO 1

MISO

SCK

MOSI

SS

SS 2
MOSI 3
SCK 4

⚠️ Don't forget to connect all the ground wires together!
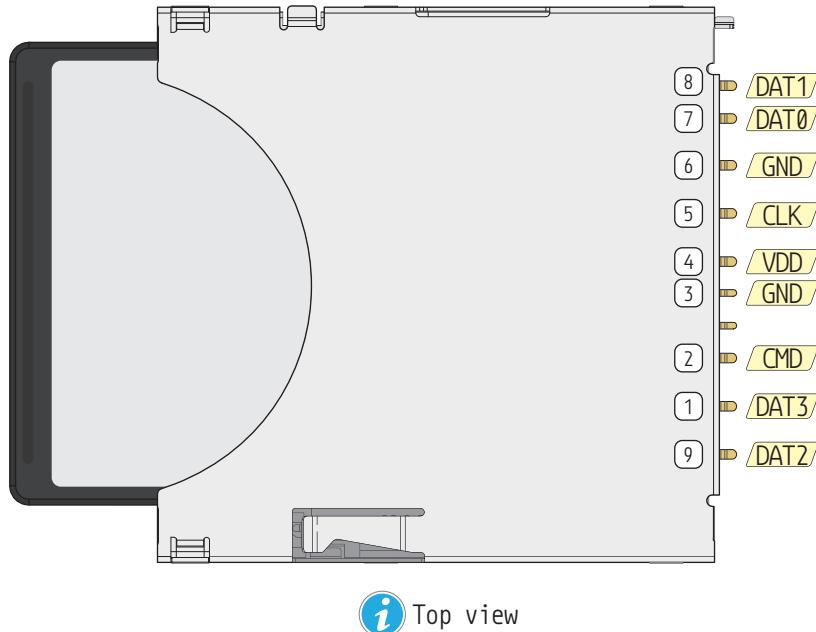
💡 If you want to have a more professional, reliable and faster SD card reader you can opt for building this circuit using the 4050 buffer/converter instead of the DIY SD card reader circuit.

SD Card Socket
Pinout

8	DAT1
7	DAT0
6	GND
5	CLK
4	VDD
3	GND
2	CMD
1	DAT3
9	DAT2

ⓘ Top view

DAT0	MISO
DAT3	SS
CMD	MOSI
CLK	SCK

82
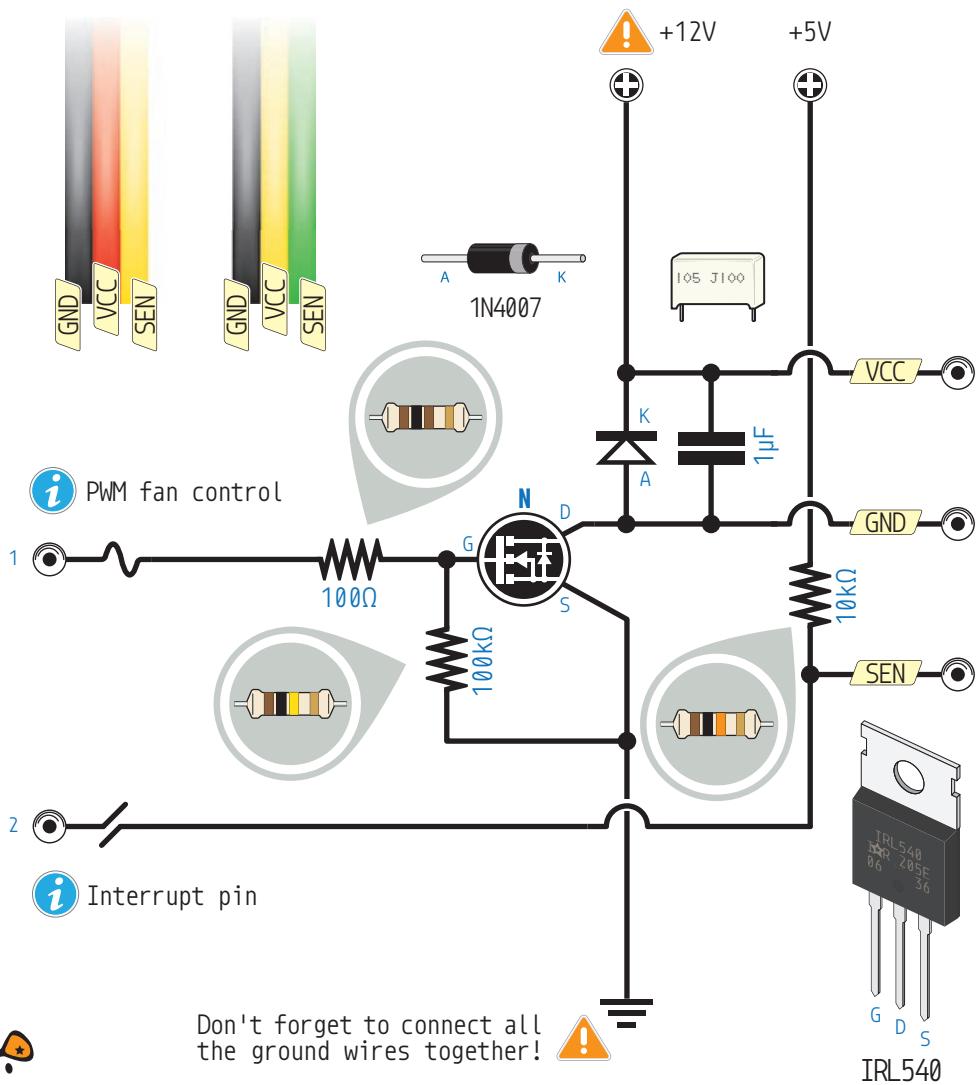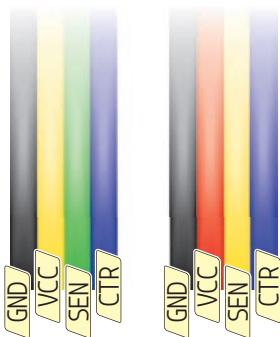
4-Wire Computer Fan
Basic Connections

⚠ PWM operating range 21kHz to 28kHz

⚠ +12V

GND VCC SEN CTR

GND VCC SEN CTR

VCC

10kΩ

ℹ Interrupt pin

2

SEN

10kΩ

A   K

3V3

1

CTR

ℹ PWM fan control

4.7kΩ

K

A

GND

Don't forget to connect all the ground wires together! ⚠

83
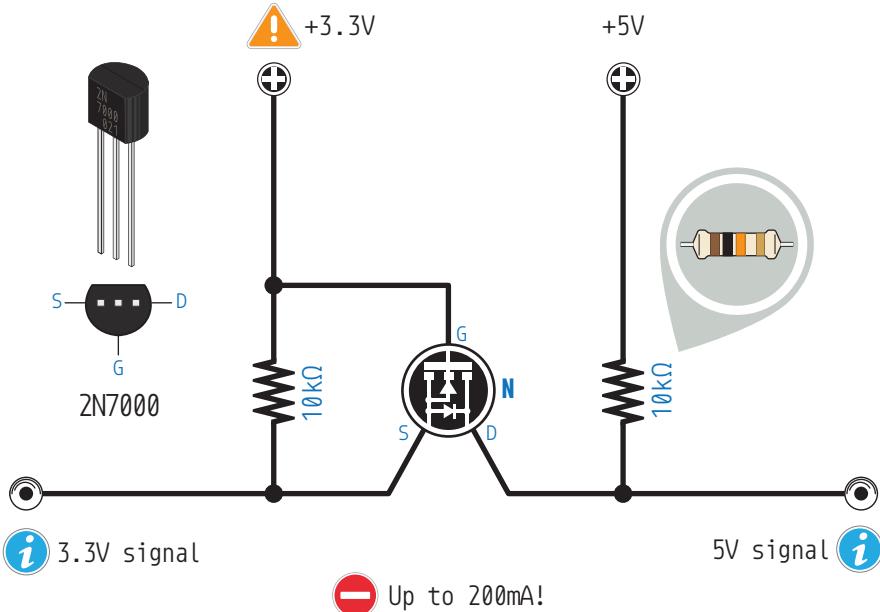
Bi-Directional Level Converter
Basic Connections

⚠ +3.3V

+5V

S ∙∙∙ D
G

G

2N7000

10KΩ

G
S   D
N

10KΩ

3.3V signal

5V signal

🚫 Up to 200mA!

Don't forget to connect all
the ground wires together! ⚠
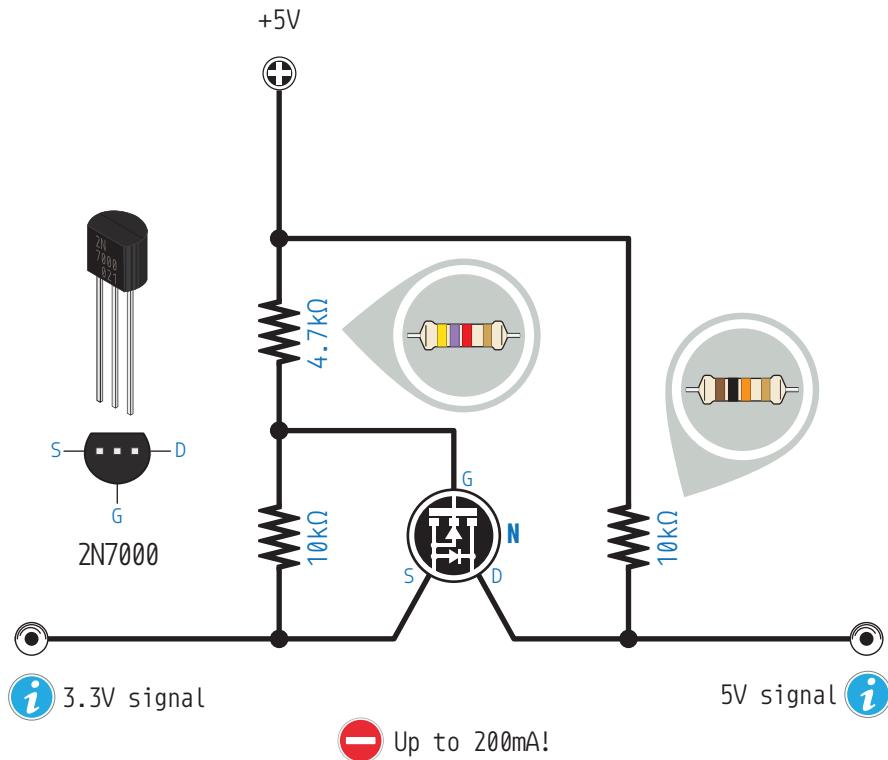
Bi-directional logic level converters allow you to connect devices that use
3.3V logic level signals to microcontroller boards that use 5V, and vice versa.
You can use both 3.3V and 5V supply voltages for this circuit or use only the
5V supply and a voltage divider to obtain 3.3V.

83

Bi-Directional Level Converter
Voltage Divider Connections

+5V

2N7000

S ●●● D

G

2N7000

4.7kΩ

10kΩ

G

N

S   D

10kΩ

3.3V signal

5V signal

🚫 Up to 200mA!

Don't forget to connect all
the ground wires together! ⚠️

0-1.es/84
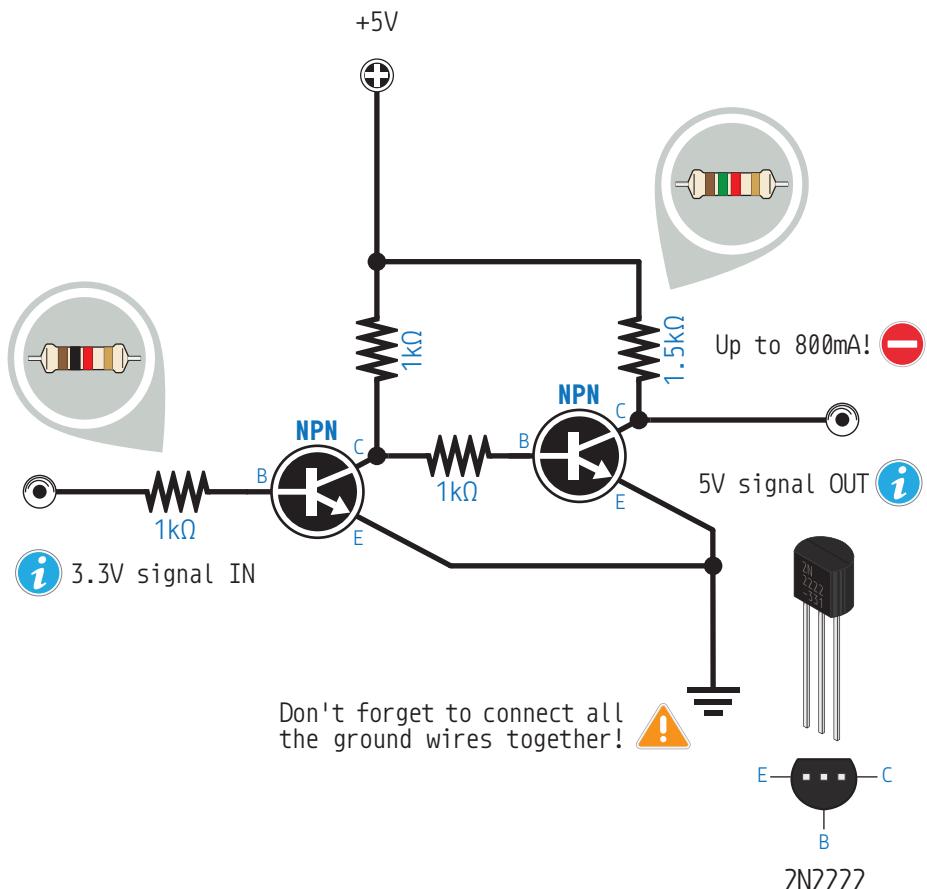
3.3V to 5V Level Shifter
Basic Connections

+5V

1kΩ

1.5kΩ

Up to 800mA! ⛔

NPN

NPN

C

B

C

E

E

5V signal OUT ℹ️

B

1kΩ

1kΩ

3.3V signal IN

ℹ️

Don't forget to connect all
the ground wires together! ⚠️

E — C

B

2N2222

Logic level shifters allow you to connect devices that use 3.3V logic level
signals to microcontroller boards that use 5V, or vice versa, depending on the
circuit you build. Logic level shifters only allow for the signal to go from one
particular logic level to another. Select the circuit according to your needs.
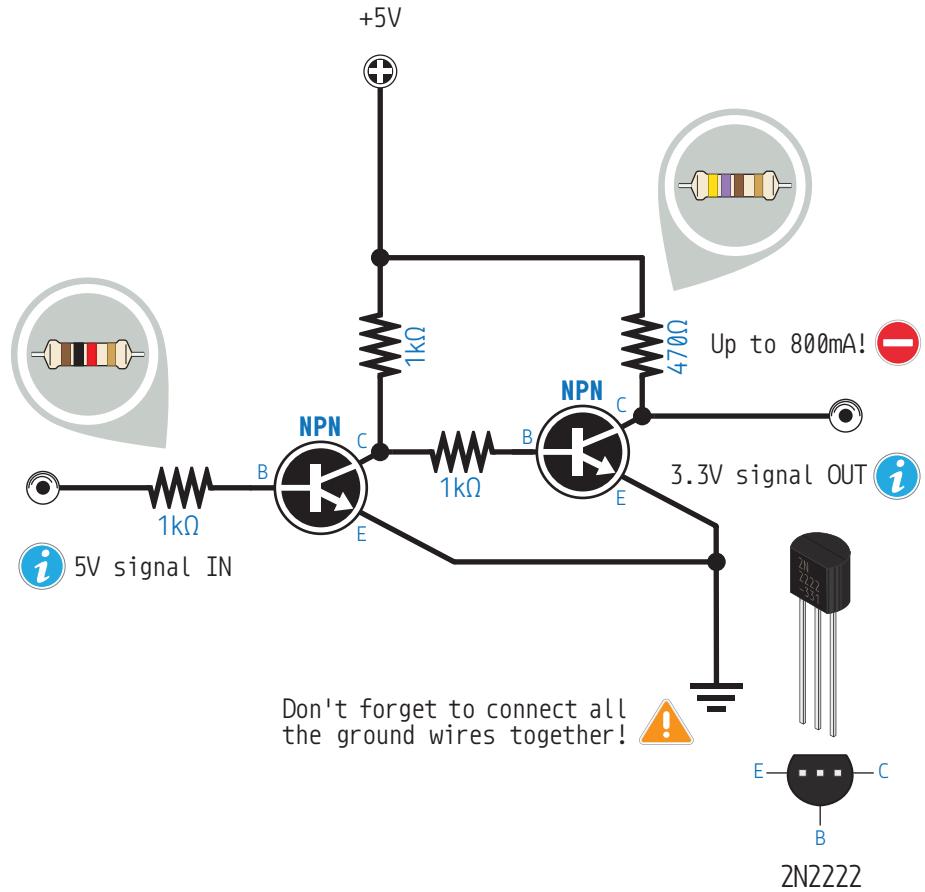
84

5V to 3.3V Level Shifter
Basic Connections

+5V

1kΩ

470Ω

Up to 800mA! 🚫

NPN

NPN

C

B

C

B

1kΩ

E

E

3.3V signal OUT ℹ️

1kΩ

B

ℹ️ 5V signal IN

Don't forget to connect all the ground wires together! ⚠️

E ⚫⚫⚫ C

B

2N2222
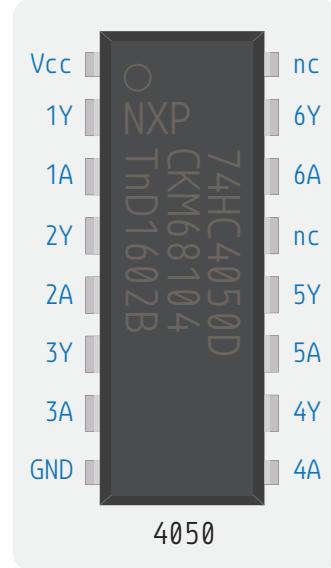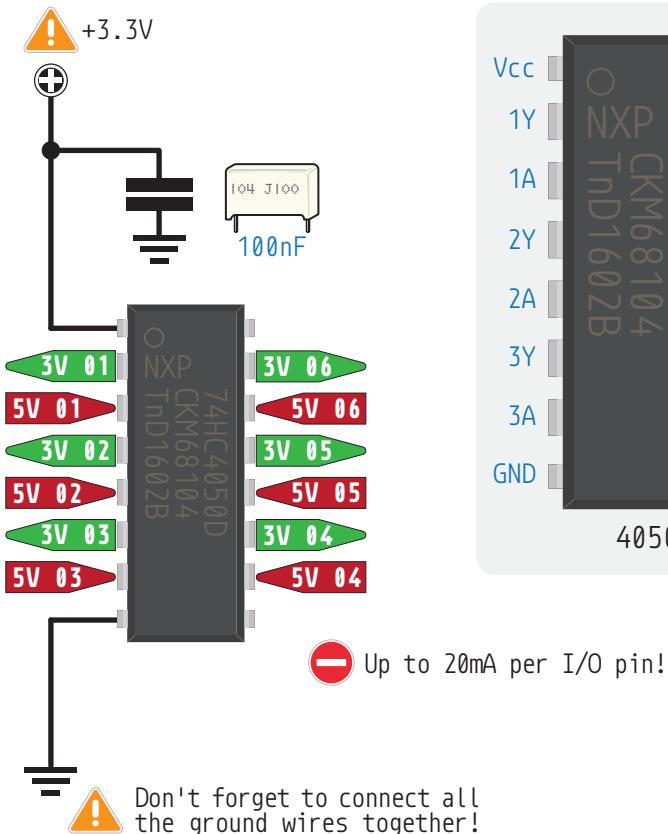
85

4050 Level Shifter
Pinout

⚠ +3.3V

⊕

104 J100

100nF

3V 01
5V 01
3V 02
5V 02
3V 03
5V 03

3V 06
5V 06
3V 05
5V 05
3V 04
5V 04

○ NXP CKM68104 TnD1602B 74HC4050D

Vcc
1Y
1A
2Y
2A
3Y
3A
GND

nc
6Y
6A
nc
5Y
5A
4Y
4A

○ NXP 74HC4050D CKM68104 TnD1602B

4050

⛔ Up to 20mA per I/O pin!

⚠ Don't forget to connect all the ground wires together!
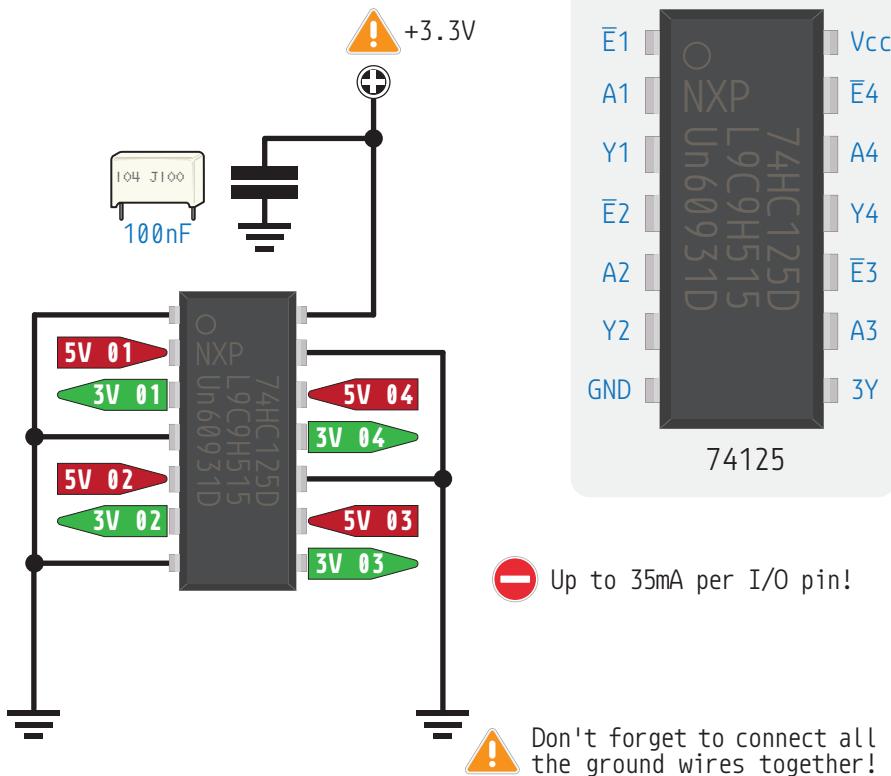
The 4050 is a hex buffer with over-voltage tolerant inputs. Inputs are overvoltage tolerant to up to 15V, which enables the device to be used in HIGH-to-LOW level shifting applications. The "hex" part means there's actually six separate buffers in one chip.

86

74125 Level Shifter
Pinout

+3.3V

104 J100

100nF

5V 01
3V 01
5V 02
3V 02

5V 04
3V 04
5V 03
3V 03

Ē1		Vcc
A1		Ē4
Y1		A4
Ē2		Y4
A2		Ē3
Y2		A3
GND		3Y

74125

⛔ Up to 35mA per I/O pin!

⚠️ Don't forget to connect all the ground wires together!
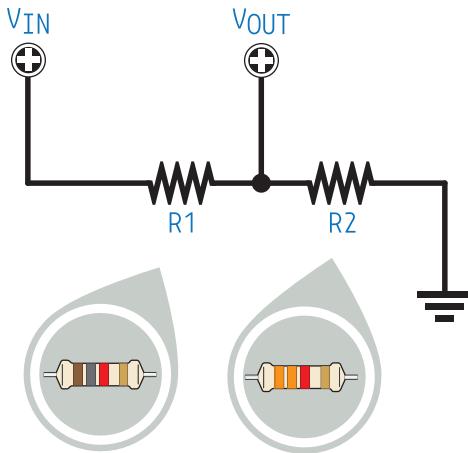
💡 The 74125 is a quad buffer/line driver with 3-state outputs controlled by the output enable inputs (E). A HIGH on E pin causes the outputs to assume a high-impedance OFF state. The "quad" part means there's actually four separate buffers/line driver in one chip.

Voltage Divider
Theory

FORMULA

$$V_{OUT} = V_{IN} \times R2 \; / \; (R1 + R2)$$
$$V_{OUT} = 5V \times 3.3k\Omega \; / \; (1.8k\Omega + 3.3k\Omega)$$
$$V_{OUT} = 3.2V$$
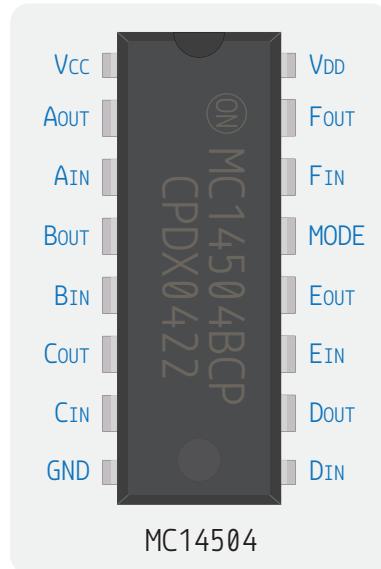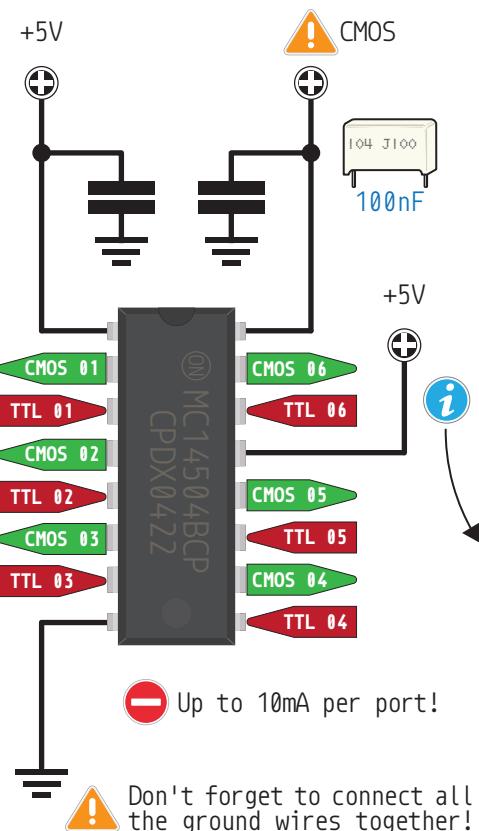
A voltage divider is a simple circuit that produces an output voltage that is a fraction of its input voltage by using just two series resistors. Voltage dividers are one of the most fundamental circuits in electronics.

88

TTL-CMOS Level Shifter
Using the MC14504

ℹ 3V to 18V operation for V_{DD} and V_{CC}

+5V

⚠ CMOS

104 J100

100nF

+5V

ℹ

V_{CC}		V_{DD}
A_{OUT}		F_{OUT}
A_{IN}		F_{IN}
B_{OUT}		MODE
B_{IN}		E_{OUT}
C_{OUT}		E_{IN}
C_{IN}		D_{OUT}
GND		D_{IN}

MC14504

CMOS 01   CMOS 06
TTL 01   TTL 06
CMOS 02
          CMOS 05
TTL 02   TTL 05
CMOS 03   CMOS 04
TTL 03   TTL 04

⛔ Up to 10mA per port!
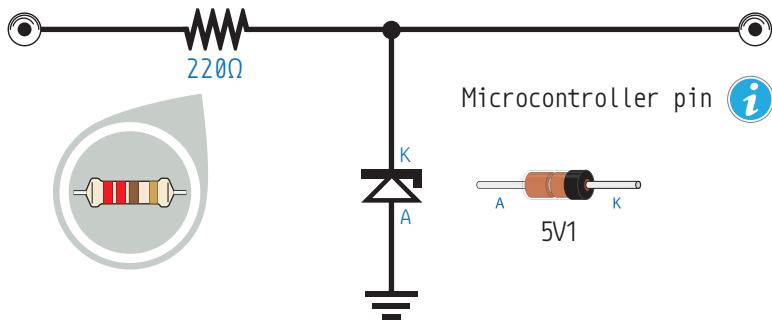
Mode select	Input logic levels	Output logic levels
1 (V_{CC})	**TTL**	**CMOS**
2 (V_{DD})	**CMOS**	**CMOS**

⚠ Don't forget to connect all the ground wires together!

💡 The MC14504x is a hex non-inverting level shifter using CMOS technology. The level shifter will shift a TTL signal to CMOS logic levels for any CMOS supply voltage between 5 and 15 volts. A control input also allows interface from CMOS to CMOS at one logic level to another logic level.

89
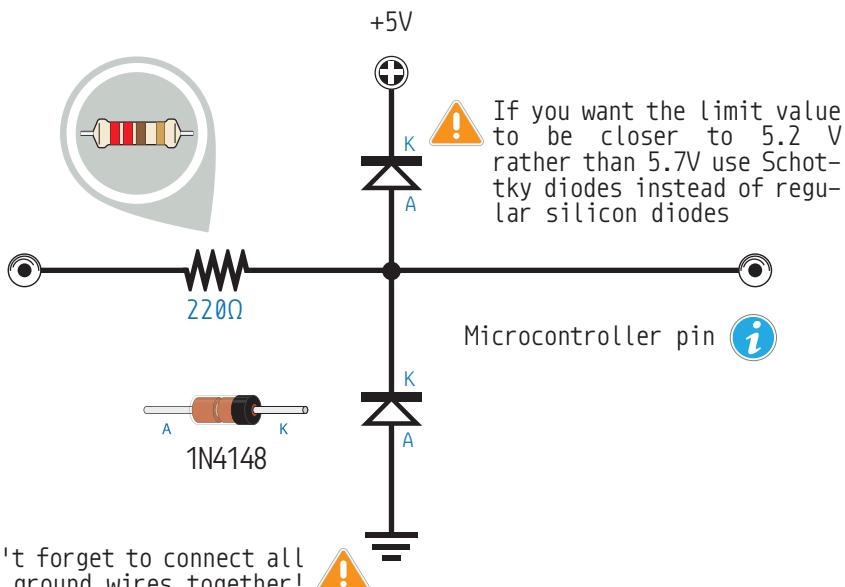
I/O Pin Protection
Using a Zener Diode

220Ω

Microcontroller pin ⓘ

K

A

5V1

Using Clamping Diodes

+5V

K

A

If you want the limit value to be closer to 5.2 V rather than 5.7V use Schottky diodes instead of regular silicon diodes

220Ω

Microcontroller pin ⓘ

K

A

1N4148

Don't forget to connect all the ground wires together! ⚠

90
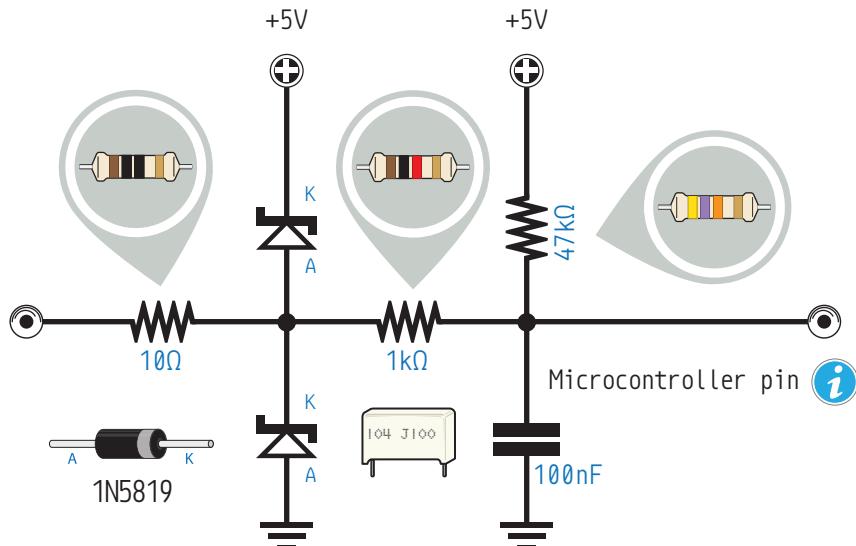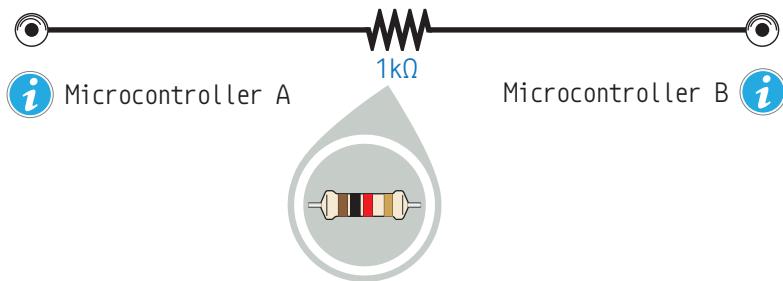
I/O Pin Filtering & Protection
Basic Connections

+5V   +5V

K
A

K   47kΩ
A

10Ω   1kΩ

Microcontroller pin ⓘ

1N5819

104 J100

100nF

Two Microcontroller Boards
Basic Connections

1kΩ

ⓘ Microcontroller A   Microcontroller B ⓘ

Don't forget to connect all
the ground wires together! ⚠

91
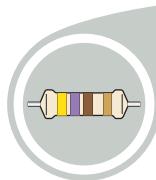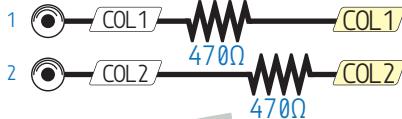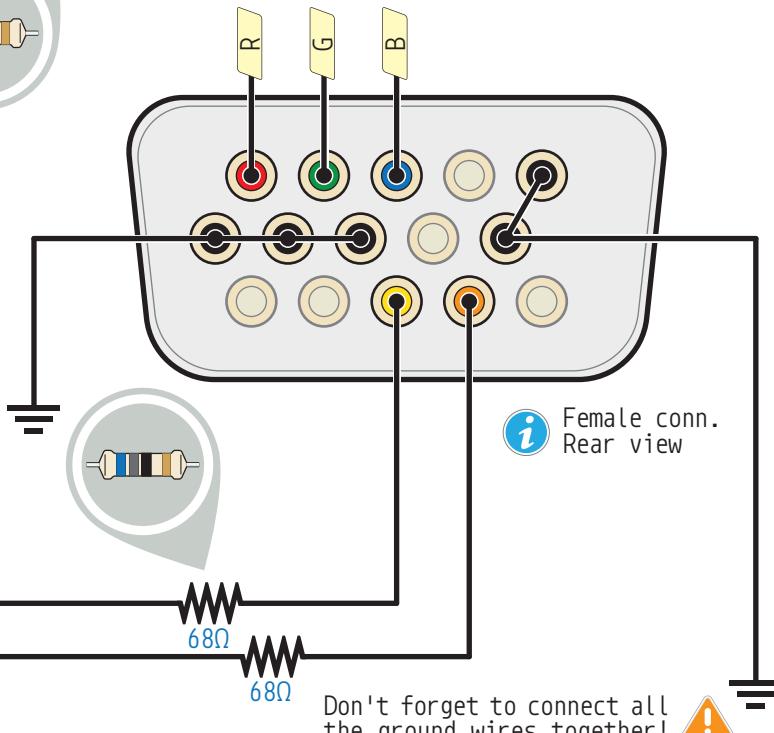
VGA Output
Basic Connections
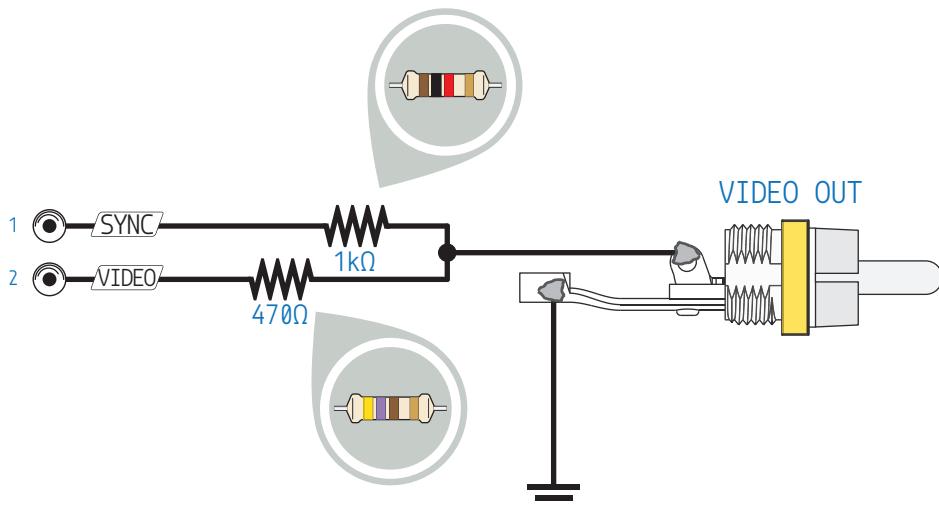
		00	01	10	11
COL1/R	COL2/G	00	01	10	11
COL1/R	COL2/B	00	01	10	11
COL1/G	COL2/B	00	01	10	11
COL1/R	COL2/G/B	00	01	10	11
COL1/R/G	COL2/B	00	01	10	11
COL1/R/B	COL2/G	00	01	10	11

1 — COL1 — 470Ω — COL1

2 — COL2 — 470Ω — COL2

R   G   B

68Ω

3 — HSYNC — 68Ω

4 — VSYNC — 68Ω

Female conn.
Rear view

Don't forget to connect all
the ground wires together!

92
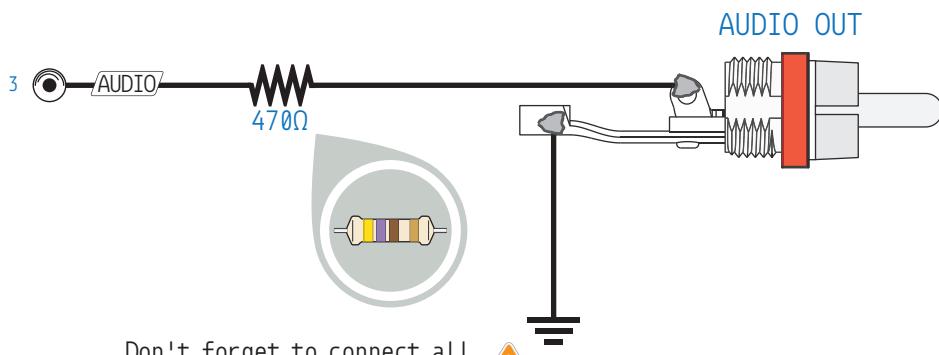
Composite Output
Basic Connections

VIDEO OUT

1 /SYNC/

1kΩ

2 /VIDEO/

470Ω

75Ω resistor required between 🛈
/VIDEO/ and GND on the RCA plug
for a very small subset of TVs

AUDIO OUT

3 /AUDIO/

470Ω
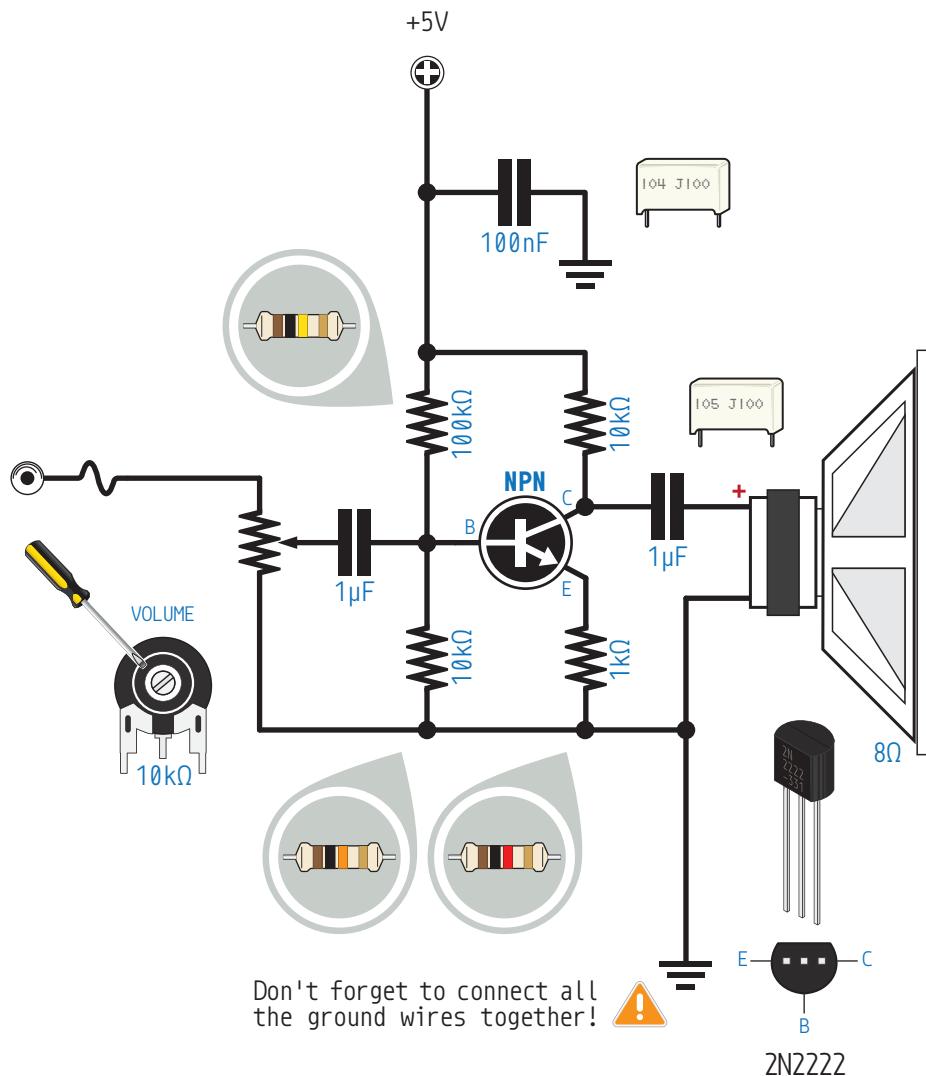
Don't forget to connect all
the ground wires together! ⚠
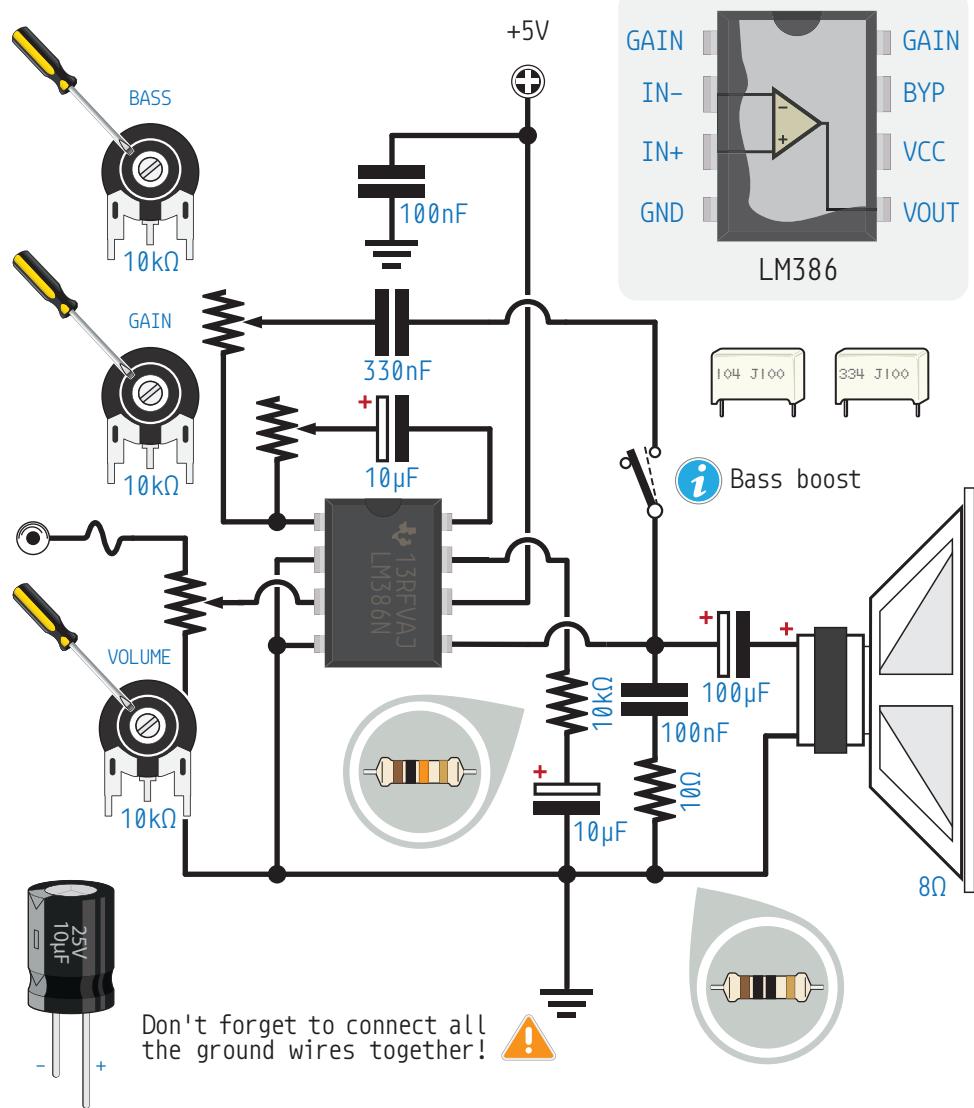
Single-Transistor Amplifier

Basic Connections

+5V

100nF

104 J100

100kΩ

10kΩ

105 J100

NPN

C

B

E

1µF

1µF

+

10kΩ

1kΩ

VOLUME

10kΩ

8Ω

2N

2222

Don't forget to connect all
the ground wires together! ⚠️

E — C

B

2N2222
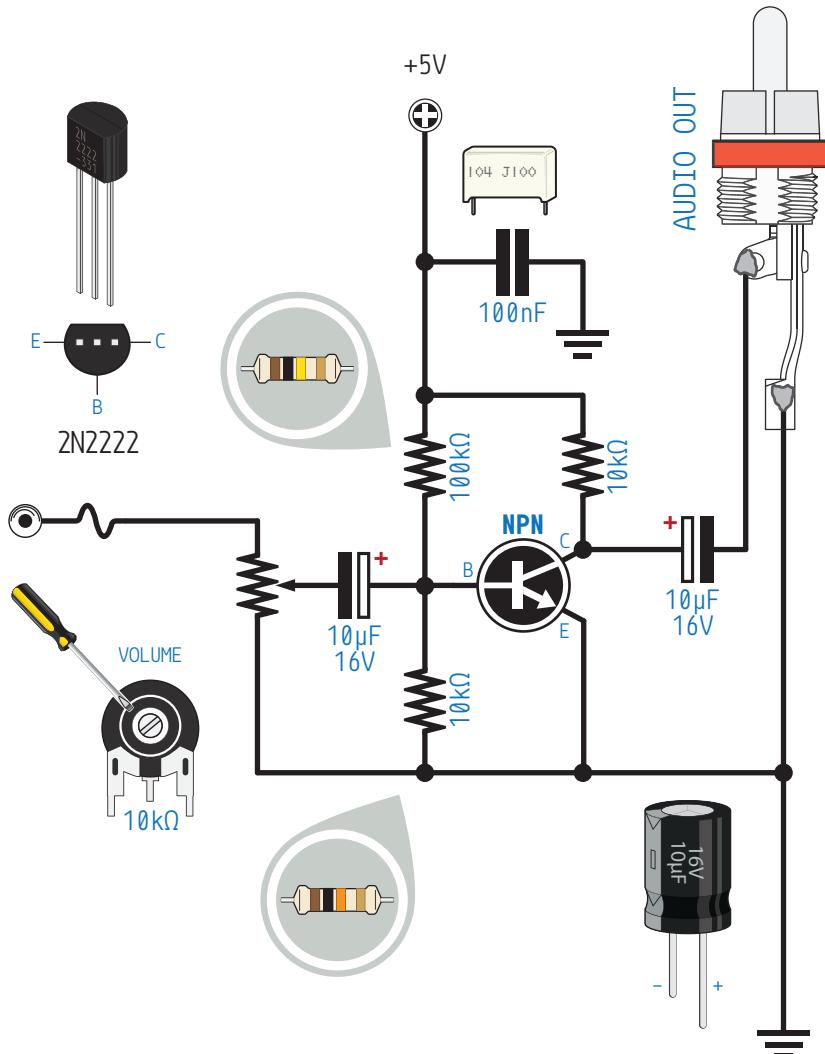
Audio Amplifier
Using the LM386 Audio Amplifier

+5V

BASS
10kΩ

GAIN
10kΩ

VOLUME
10kΩ

GAIN		GAIN
IN−		BYP
IN+		VCC
GND		VOUT

LM386

100nF

330nF

10µF

104 J100   334 J100

(i) Bass boost

13REVAJ
LM386N

10kΩ

100nF

10Ω

100µF

10µF

8Ω

25V
10µF

−   +

Don't forget to connect all
the ground wires together! ⚠

95

Preamplifier
Basic Connections

2N2222

E — C

B

2N2222

+5V

104 J100

100nF

AUDIO OUT

100kΩ

10kΩ

NPN

C

B

E

10µF
16V

+

10µF
16V

+

VOLUME

10kΩ

10µF
16V

+

10kΩ

16V
10µF

–   +

Don't forget to connect all
the ground wires together! ⚠️

96
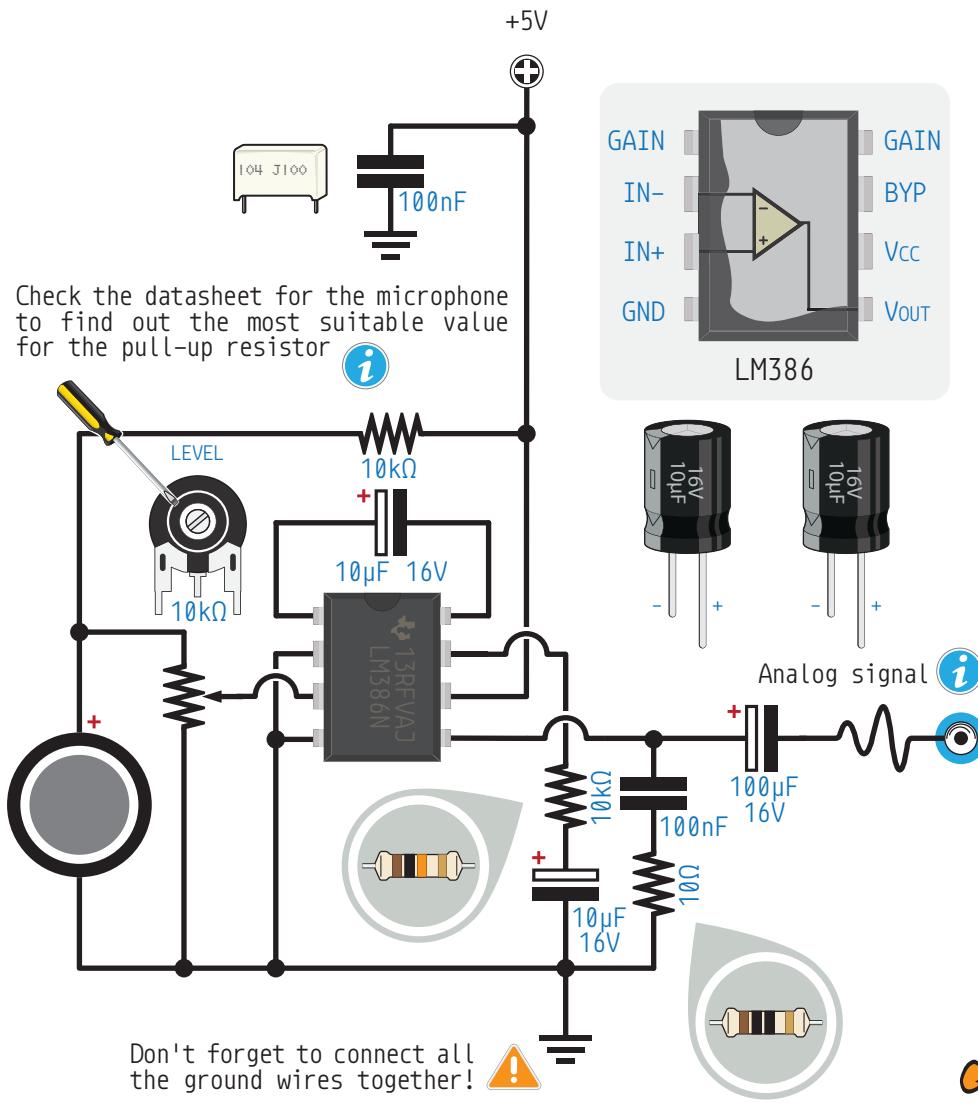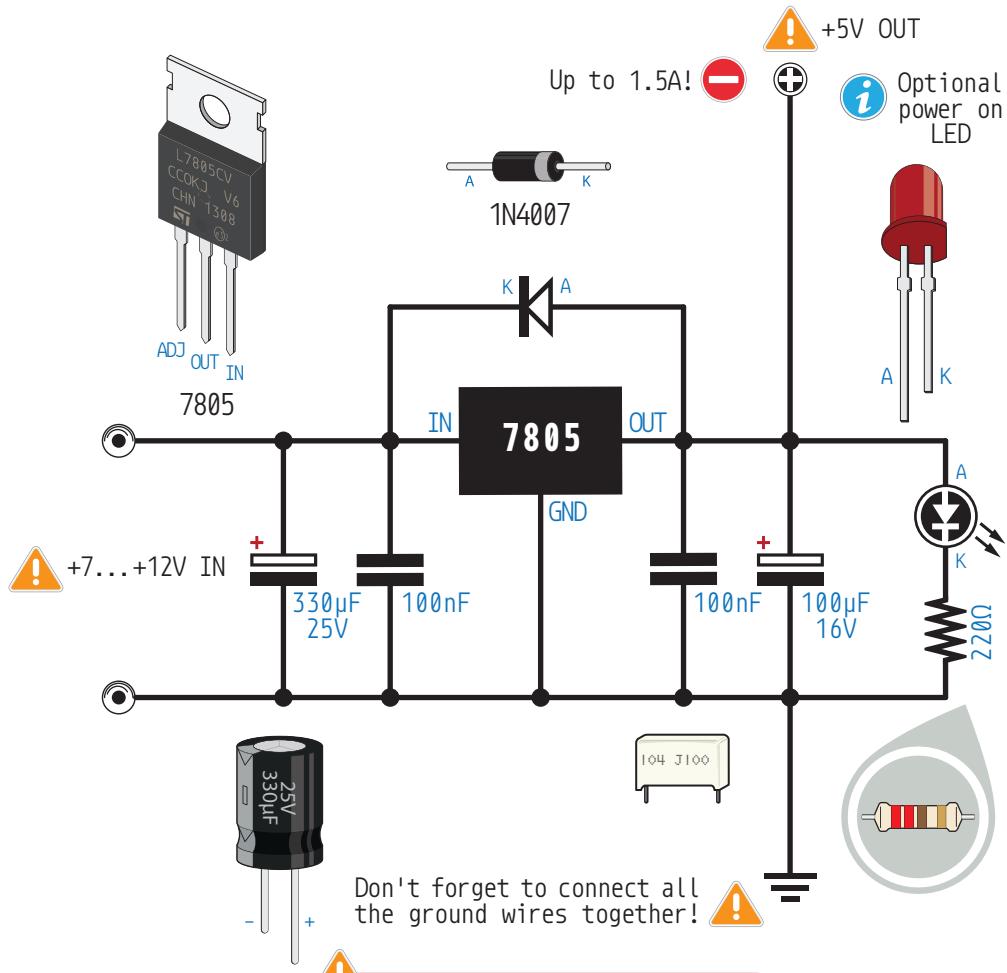
Microphone
Using the LM386 Audio Amplifier

+5V

104 J100

100nF

Check the datasheet for the microphone to find out the most suitable value for the pull-up resistor ⓘ

LM386

GAIN — GAIN
IN– — BYP
IN+ — Vcc
GND — Vout

LEVEL

10kΩ

10kΩ

10µF 16V

13RFVAJ LM386N

16V 10µF

16V 10µF

– +

– +

Analog signal ⓘ

+

10kΩ

100nF

+

10µF 16V

10Ω

+

100µF 16V

Don't forget to connect all the ground wires together! ⚠

97

Simple 5V Power Supply
Basic Connections

⚠️ +5V OUT

Up to 1.5A! ⛔ ➕

ℹ️ Optional power on LED

L7805CV
CCOKJ V6
CHN 1308
ST

1N4007

A   K

ADJ OUT IN
7805

K ◁ A

IN   **7805**   OUT

GND

⚠️ +7...+12V IN

+
330µF
25V

100nF

100nF

+
100µF
16V

A
⊗
K

220Ω

25V
330µF

−   +

104 J100

Don't forget to connect all the ground wires together! ⚠️

⚠️
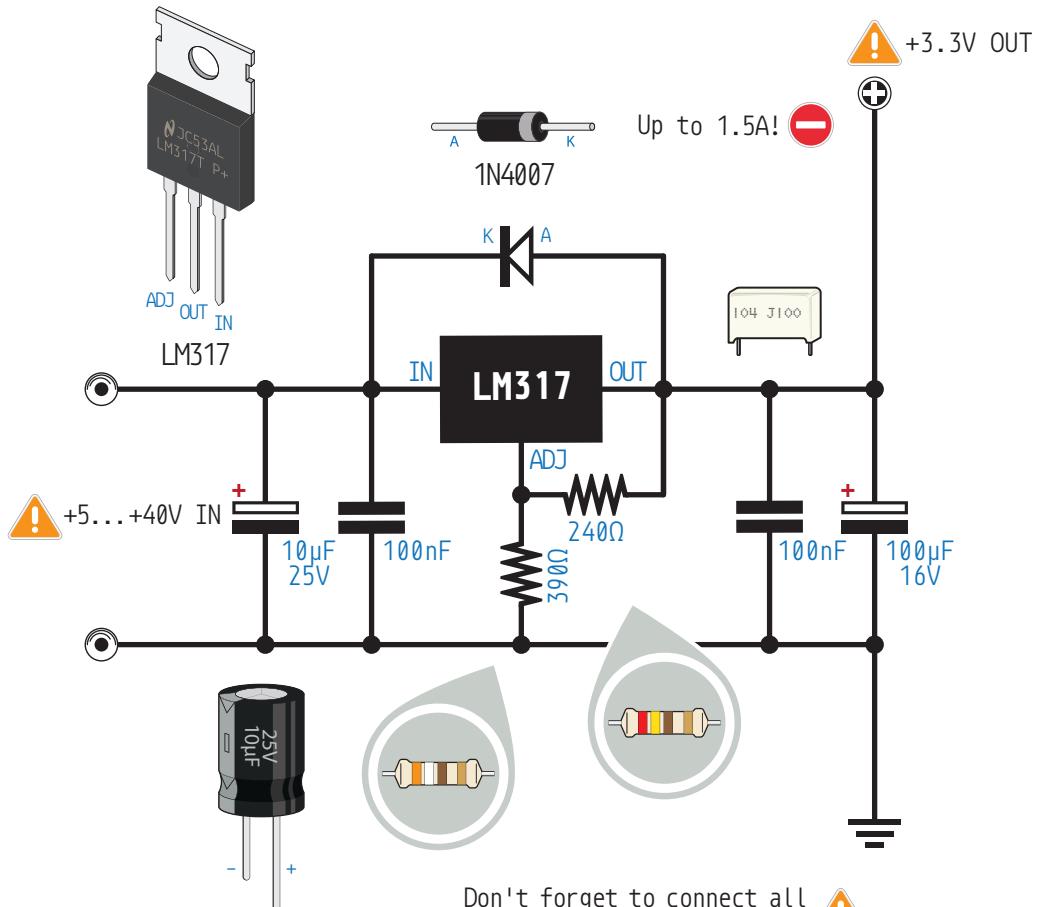
Don't forget to attach a heat sink to the 7805 if are connecting a high-power load!

98

Simple 3.3V Power Supply
Basic Connections
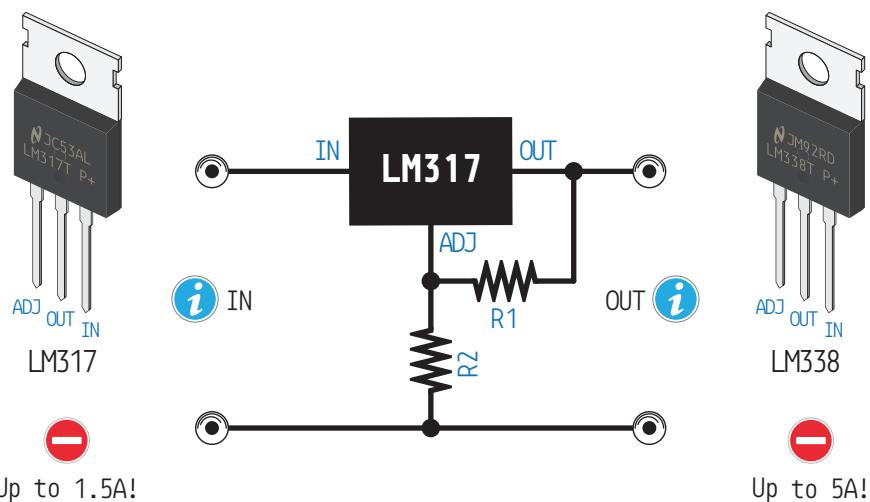
LM317

JC53AL
LM317T P+

ADJ OUT IN

1N4007

A   K

Up to 1.5A! ⛔

+3.3V OUT ⚠

K ◁| A

104 J100

IN **LM317** OUT

ADJ

240Ω

390Ω

+5...+40V IN ⚠

+
10µF
25V

100nF

100nF

+
100µF
16V

25V
10µF

–   +

Don't forget to connect all
the ground wires together! ⚠

⚠ Don't forget to attach a heat
sink to the LM317 if are
connecting a high-power load!

99

Simple Adjustable Power Supply

Using the LM317 Voltage Regulator

LM317

Up to 1.5A!

IN

OUT

LM317

IN → OUT

ADJ

R1

R2

LM338

Up to 5A!

i You can use a trimmer instead of R1 and R2 to adjust the output voltage manually

$$V_{OUT} = 1.25 \times (1 + (R2 / R1))$$
$$V_{OUT} = 1.25 \times (1 + (390 / 240))$$
$$V_{OUT} = 3.28V$$
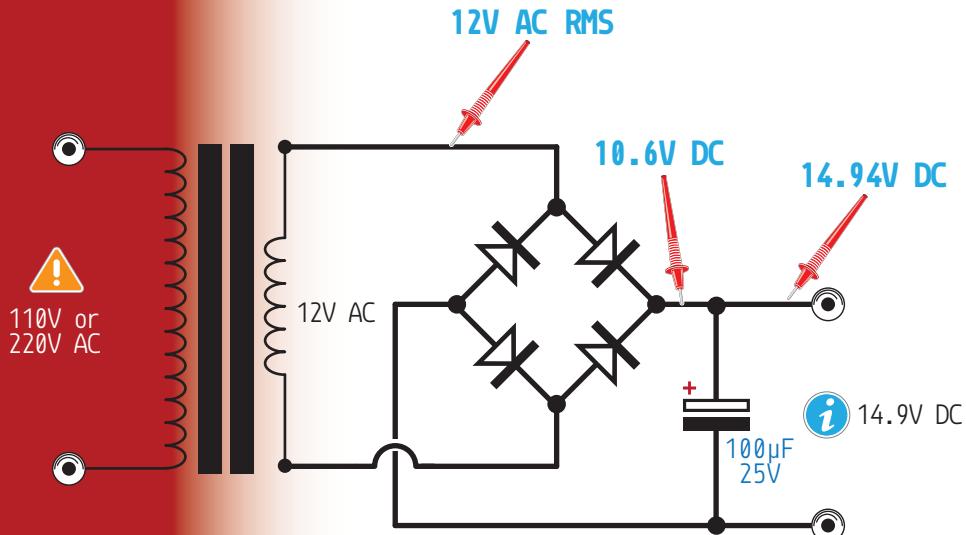
V_{OUT}	R1	R2
3.3V	240Ω	390Ω
5V	240Ω	750Ω
6V	240Ω	1kΩ
9V	240Ω	1.5Ω

100
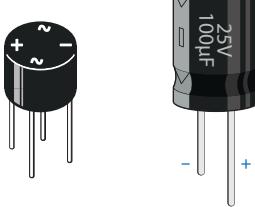
Full-Wave Rectifier
Basic Connections

12V AC RMS

10.6V DC

14.94V DC

110V or
220V AC

12V AC

+

100µF
25V

14.9V DC

Bridge Rectifier

~

+ ~

25V
100µF

–   +

When using a bridge rectifier and a capacitor

$$V_{OUT} = (V_{IN} - 1.4) \times 1.41$$
$$V_{OUT} = (12 - 1.4) \times 1.41$$
$$V_{OUT} = \textbf{14.946V}$$

WARNING!

Mains voltage electricity is very dangerous. There is a high risk of death through electrocution if mains electricity is allowed to pass through your body, adding to the risk of fire or explosion if electricity is not cabled and fused correctly. NEVER connect mains voltage to a breadboard!

Use the instructions and suggestions in ABC: Basic Connections at your own risk. PighiXXX and the author disclaim all responsibility for any resulting damage, injury, or expense. It is your responsibility to make sure that your activities comply with the safety precautions.

WARNING!
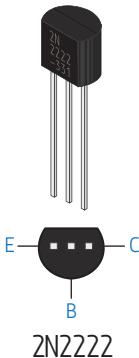
Generally, dealing with voltages lower than 50V is relatively safe, but anything above that can be dangerous. Always make the proper connections with the wires disconnected from the power outlet. Isolation between wires and other parts of the circuit that work at lower voltages is crucial. Always use wires rated for the voltage and current applied to them. This also applies, specifically for current, for all circuits covered in this book.

Unless otherwise stated, do not connect DC signal ground (GND) and AC ground (earth) together!
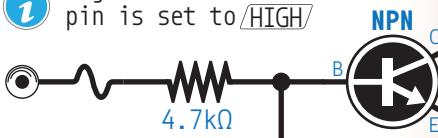
101

TRIAC
Using the MOC3023S

+5V

2N2222

680Ω

330Ω

MOC3023

TRIAC

A2

S

A1

NPN

C

B

E

4.7kΩ

4.7kΩ
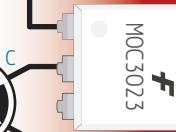
Light turns on when pin is set to /HIGH/

BTA08-600

T1 T2 G

Don't forget to connect all the ground wires together!
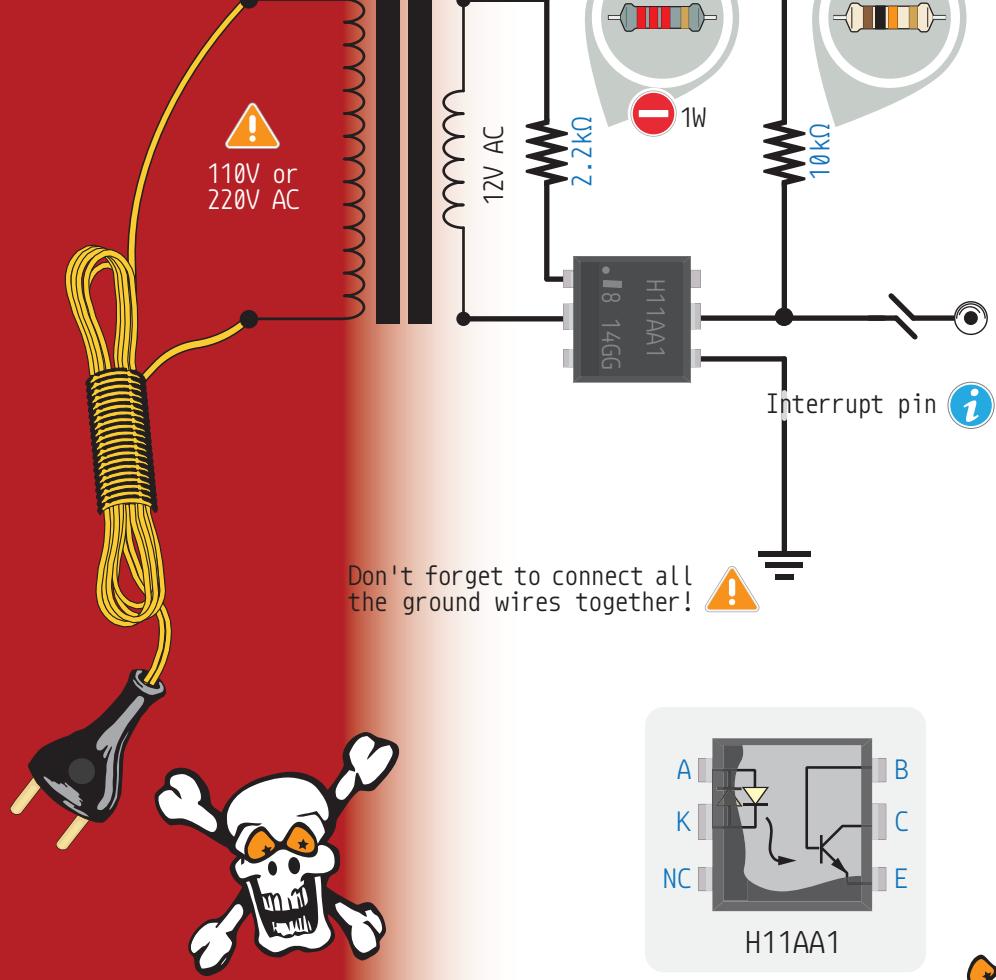
102

Zero-Crossing Detector
Using the H11AA1 Optocoupler

+5V

110V or
220V AC

12V AC

2.2kΩ

1W

10kΩ

H11AA1
8 14GG

Interrupt pin

Don't forget to connect all
the ground wires together!

A		B
K		C
NC		E
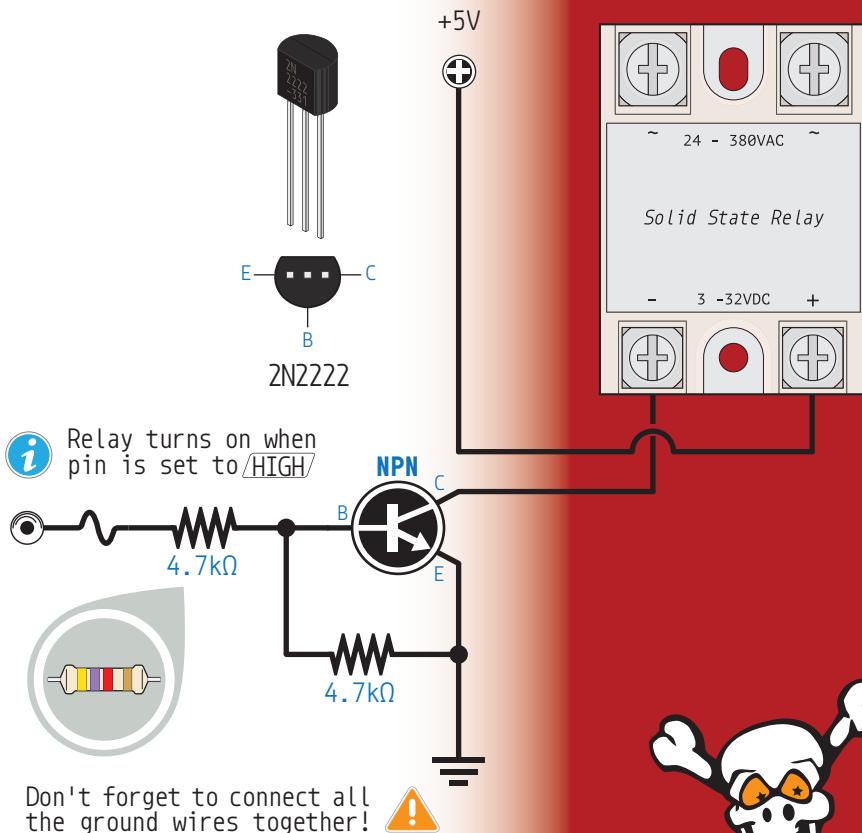
H11AA1

103
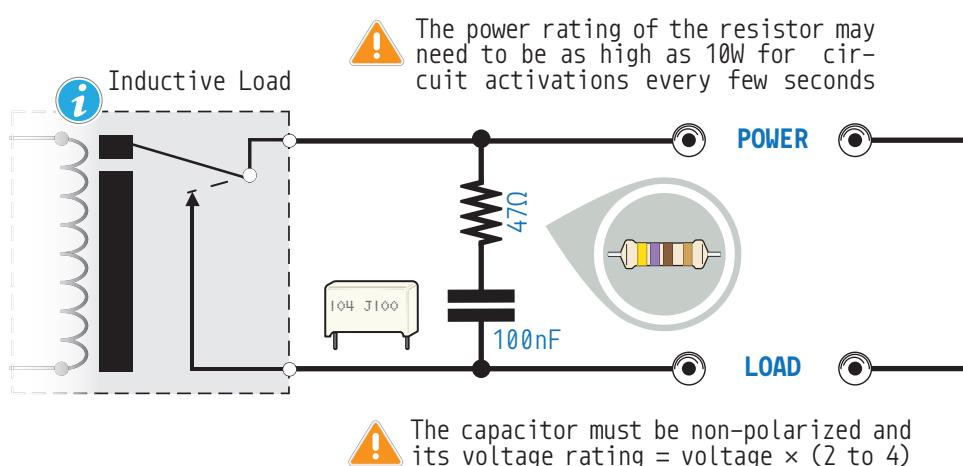
Solid-State Relay
Basic Connections

+5V

2N2222

E ⚬⚬⚬ C

B

2N2222

~   24 - 380VAC   ~

Solid State Relay

−   3 -32VDC   +

ⓘ Relay turns on when pin is set to HIGH

NPN

C

B

E

4.7kΩ

4.7kΩ

Don't forget to connect all the ground wires together! ⚠

104

RC Snubber Network
Theory

The power rating of the resistor may need to be as high as 10W for circuit activations every few seconds

Inductive Load

47Ω

104 J100

100nF

POWER

LOAD

The capacitor must be non-polarized and its voltage rating = voltage × (2 to 4)

FORMULA

$$C = \frac{I^2}{10} \qquad R(\Omega) = \frac{E}{10 \times I \times (I + \frac{50}{E})}$$

SIMPLE FORMULA

R(Ω) = voltage(V) × (.5 to 1)
C(µF) = current(A) × (.5 to 1)

Standard values are 47Ω for the resistor and 100nF for the capacitor
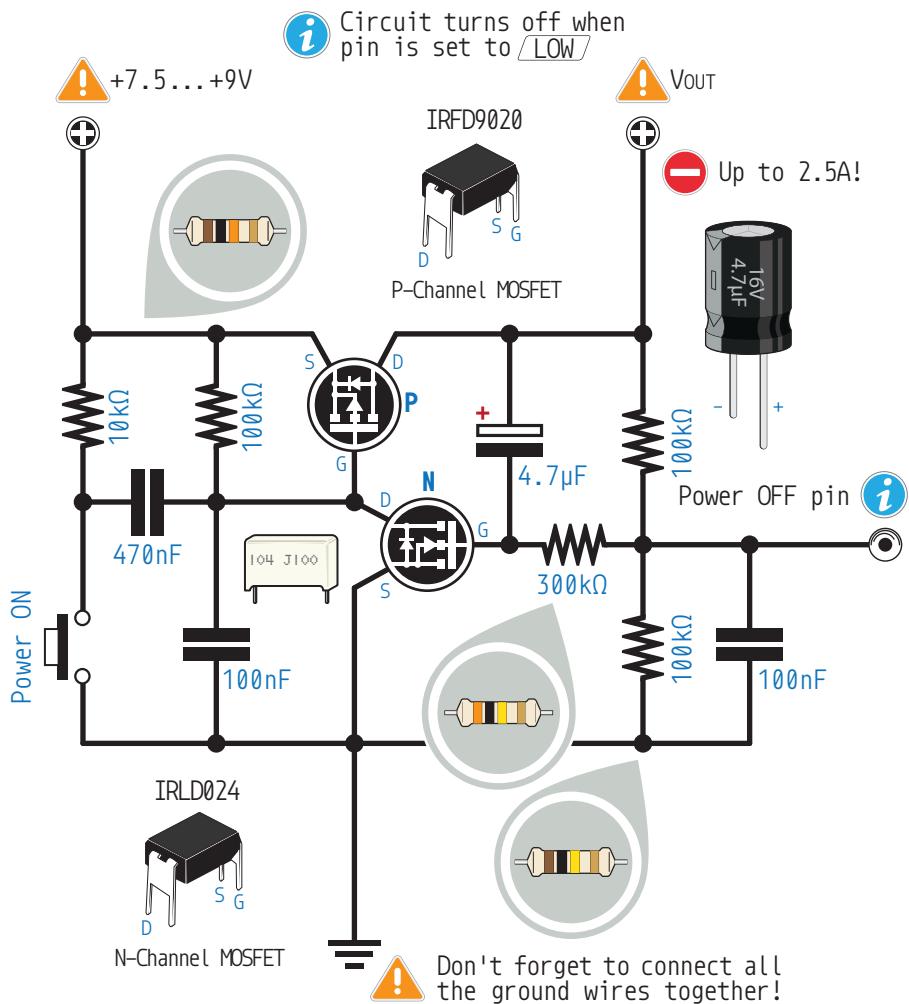
Snubbers are used in electrical systems with an inductive load where the sudden interruption of current flow leads to a sharp rise in voltage across the current switching device. A simple RC snubber uses a resistor and a capacitor in series to suppress a rapid rise in voltage.

105
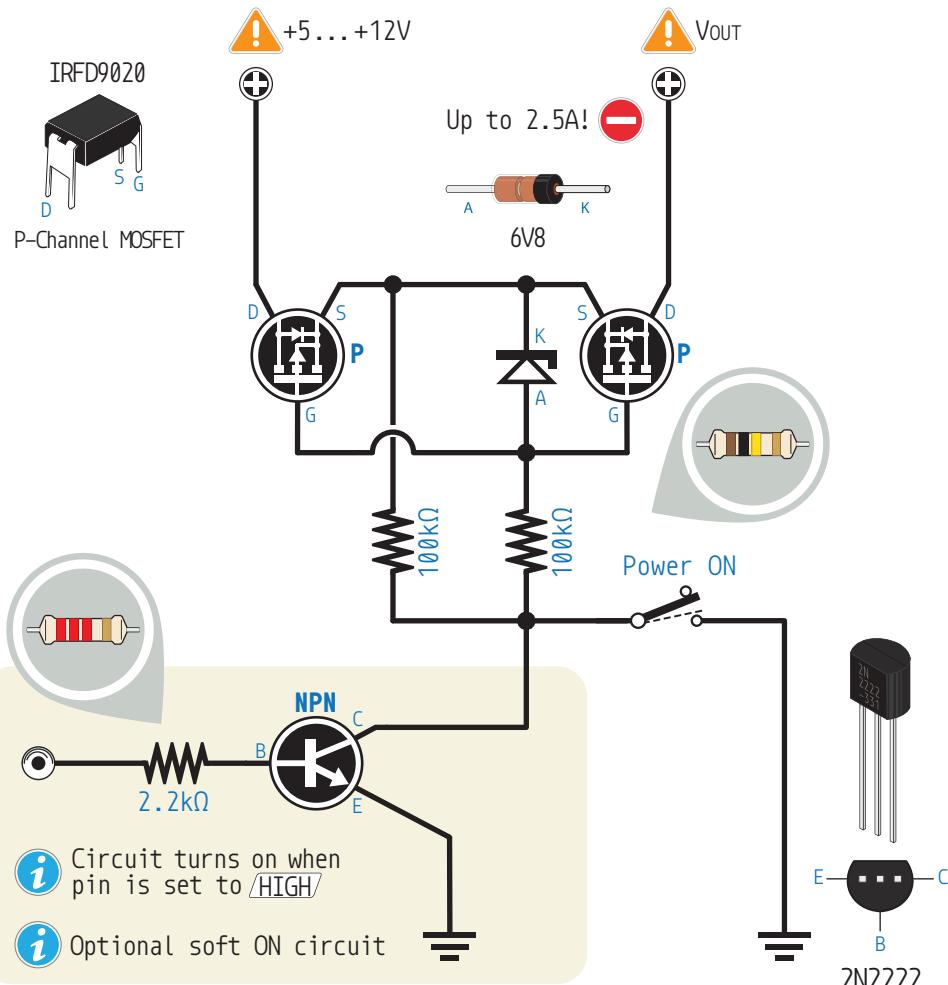
Soft Latching Power ON Switch
Basic Connections

ⓘ Circuit turns off when pin is set to / LOW /

⚠ +7.5...+9V

⚠ Vᴏᴜᴛ

IRFD9020

S G
D

P–Channel MOSFET

🚫 Up to 2.5A!

16V 4.7μF

S D
P
G

10kΩ

100kΩ

+
4.7μF

100kΩ

– +

Power OFF pin ⓘ

D N
G
S

470nF

104 J100

300kΩ

Power ON

100nF

100kΩ

100nF

IRLD024

S G
D

N–Channel MOSFET

⚠ Don't forget to connect all the ground wires together!

106

Reverse Voltage Protection
Basic Connections

IRFD9020

S G
D
P–Channel MOSFET

⚠ +5...+12V

⊕

V_{OUT} ⚠

⊕

Up to 2.5A! ⛔

A   K
6V8

D   S   S   D
   P   P
G   G

K
A

100kΩ   100kΩ

Power ON

NPN
B   C
E
2.2kΩ

ⓘ Circuit turns on when
   pin is set to HIGH

ⓘ Optional soft ON circuit

2N2222
E   C
B

Don't forget to connect all
the ground wires together! ⚠

107
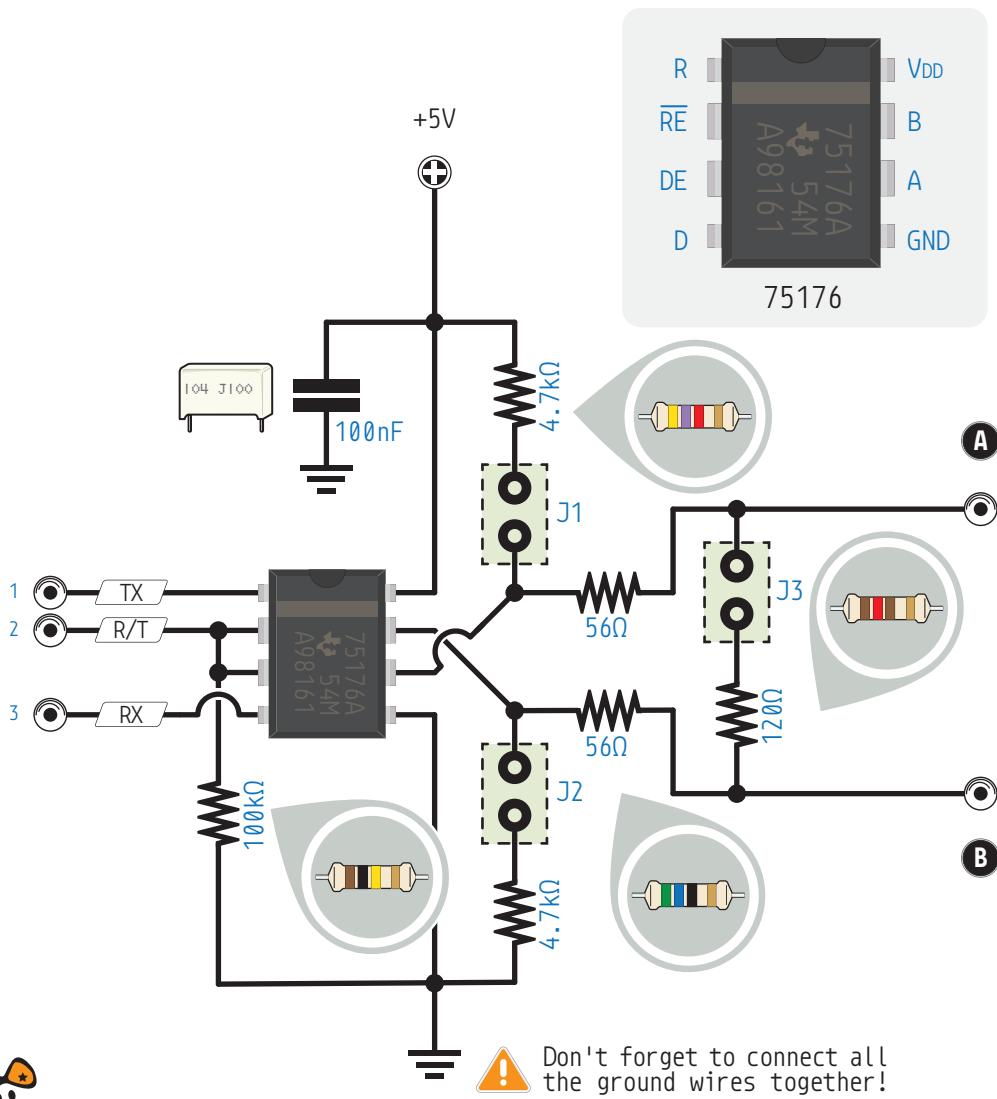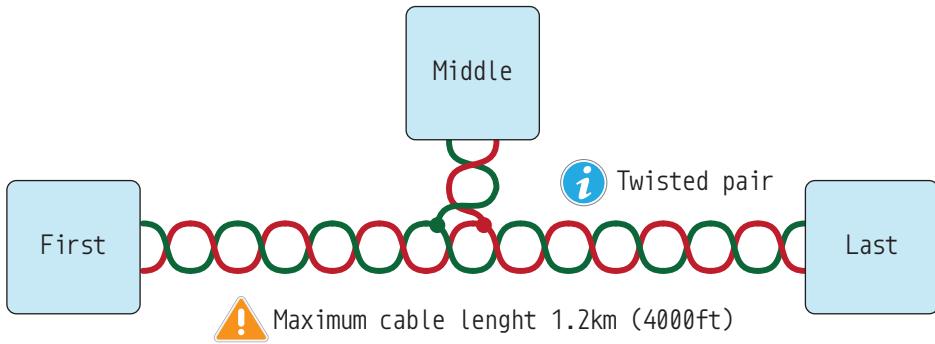
RS-485 Interface
RS-485 Node Using the 75176 Transceiver

75176

R			V_DD
$\overline{RE}$			B
DE			A
D			GND

+5V

104 J100

100nF

4.7kΩ

J1

56Ω

J3

120Ω

A

1   TX

2   R/T

3   RX

75176A
54M
A98161

100kΩ

J2

4.7kΩ

56Ω

B

Don't forget to connect all
the ground wires together!

107

RS-485 Interface
Node Termination Jumpers

Middle

ⓘ Twisted pair

First

Last

⚠ Maximum cable lenght 1.2km (4000ft)

First Node

J1
J2
J3

Middle Node

J1
J2
J3

Last Node

J1
J2
J3

Maximum number of drivers and receivers per line: 32
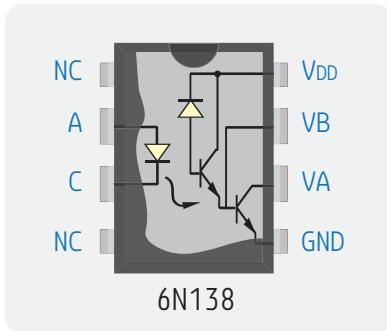
💡 RS-485 is a standard for serial communication transmission of data, especially useful to transmit data over long distances and in electrically noisy environments. Typical applications are process automation (chemicals, brewing, paper mills), factory automation, security, and motor control.

108
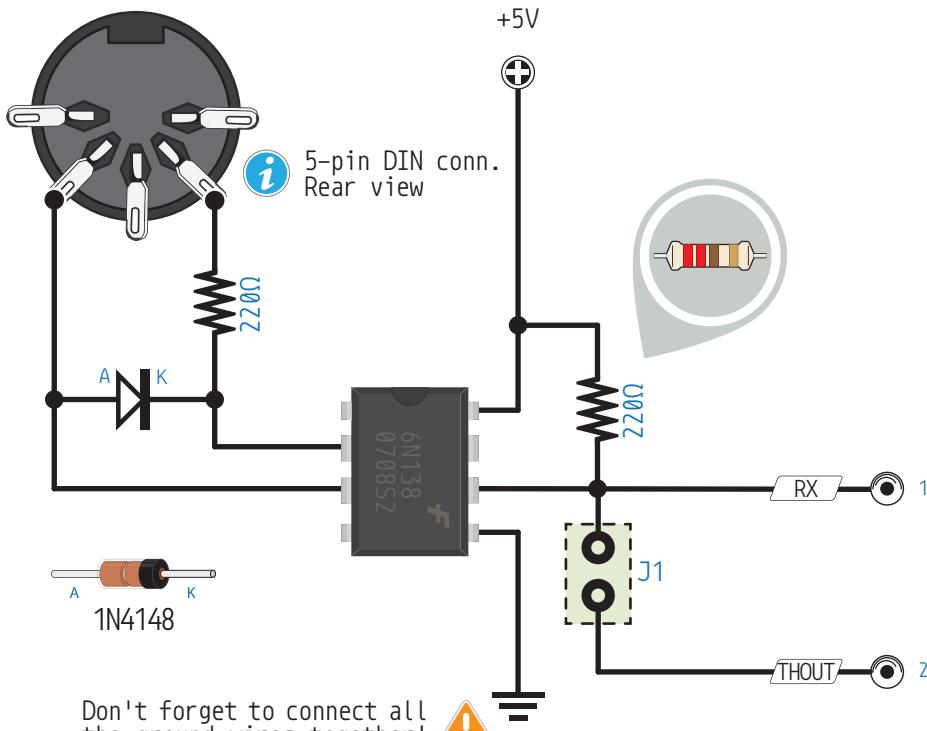
MIDI IN
Using the 6N138 Optocoupler

NC — VDD
A — VB
C — VA
NC — GND

6N138
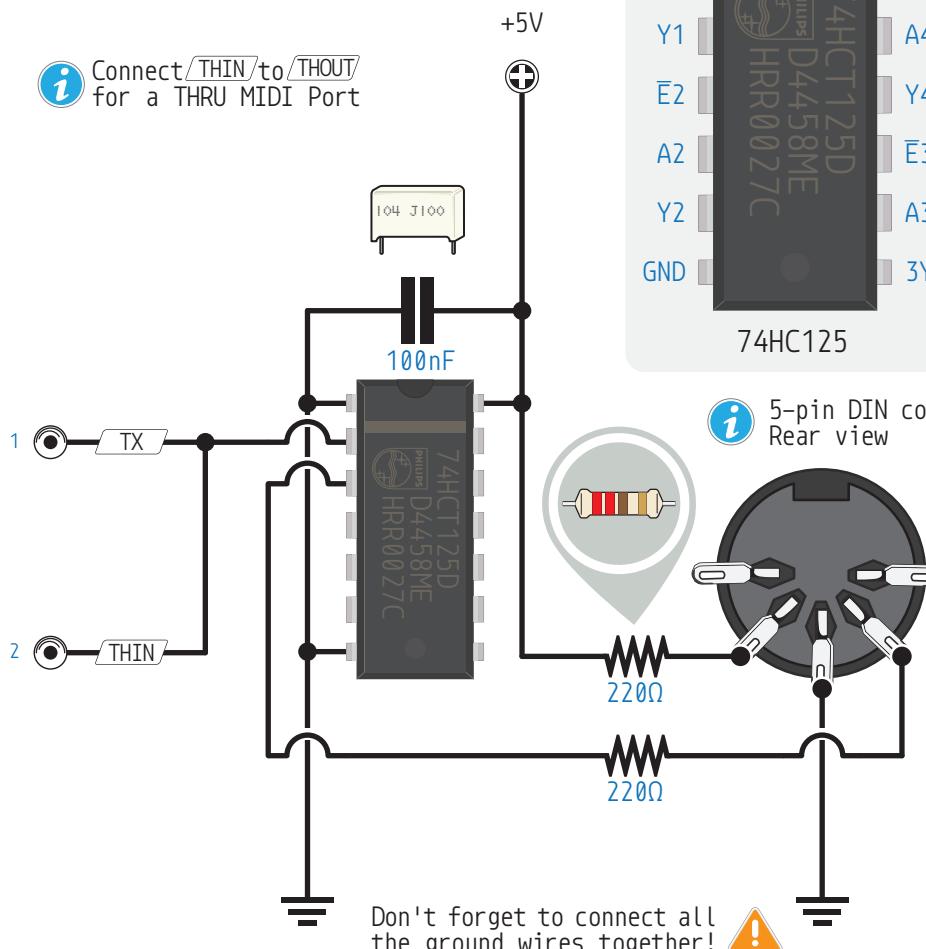
ℹ️ Short J1 to copy data stream from the input to the THRU port

ℹ️ 5-pin DIN conn. Rear view

+5V

220Ω

A K

220Ω

6N138
0708S2

1N4148

A K

RX — 1

J1

THOUT — 2

Don't forget to connect all the ground wires together! ⚠️

109
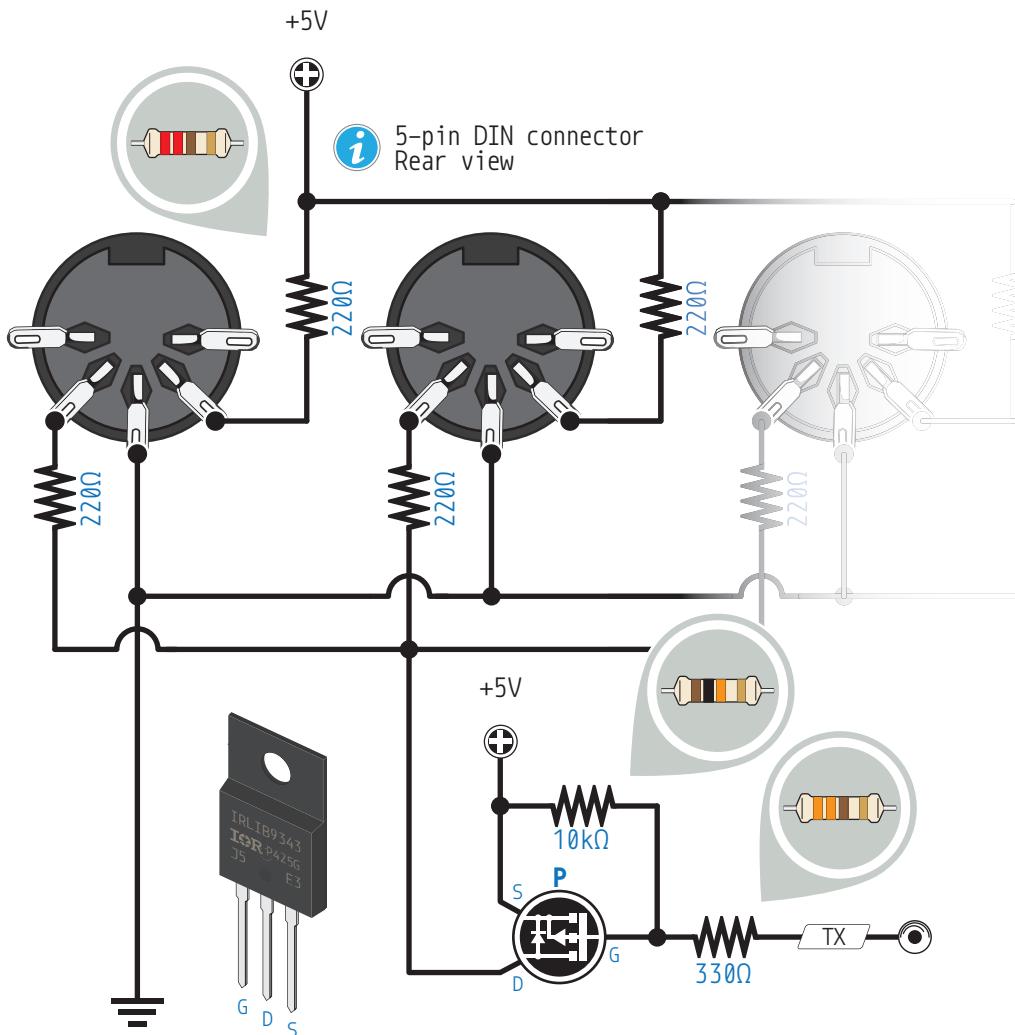
MIDI OUT
Using the 74HCT125 Bus Buffer

Ē1	Vcc
A1	Ē4
Y1	A4
Ē2	Y4
A2	Ē3
Y2	A3
GND	3Y

74HC125

+5V

i Connect /THIN/ to /THOUT/ for a THRU MIDI Port

104 J100

100nF

i 5-pin DIN connector Rear view

1 TX

2 THIN

74HCT125D D4458ME HRR0027C

220Ω

220Ω

Don't forget to connect all the ground wires together! ⚠️

110

Multiple MIDI OUT
Basic Connections

+5V

5-pin DIN connector
Rear view

220Ω
220Ω
220Ω
220Ω
220Ω
220Ω

+5V

10kΩ

P

S

G

D

330Ω

TX

IRLIB9343
I⊗R P425G
J5   E3

G D S
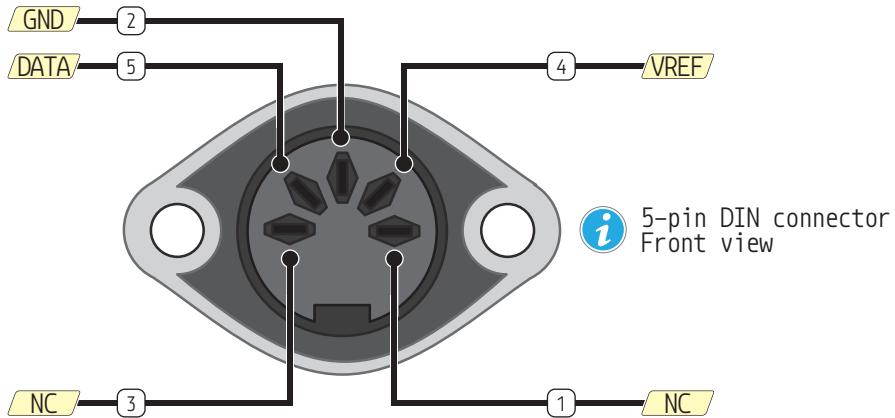
IRLIB9343

⚠ Don't forget to connect all
the ground wires together!

110

MIDI
Pinout

GND — 2

DATA — 5

4 — VREF

i 5-pin DIN connector
Front view

NC — 3

1 — NC
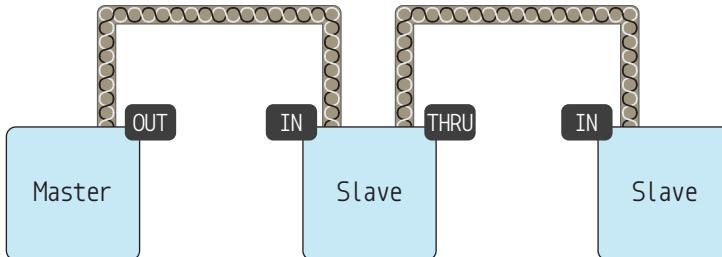
i Pins 3 and 1 are used for implementing power over MIDI

MIDI Daisy Chain

i Shielded twisted pair

OUT | IN | THRU | IN

Master | Slave | Slave
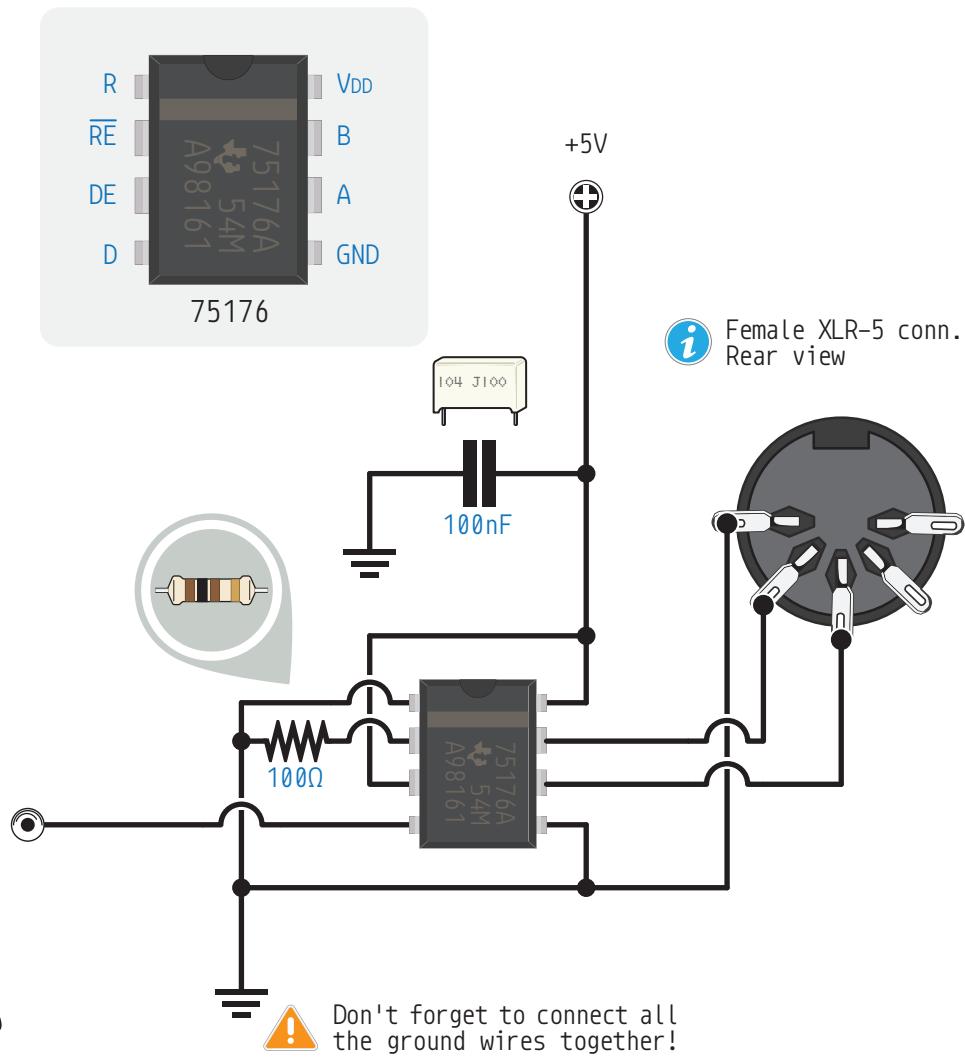
MIDI is a widely-used protocol that allows a wide variety of electronic musical instruments, computers and other related devices to connect and communicate with one another. You can build a MIDI controller with your microcontroller board and connect it to your computer to control a sequencer and play music!

111

DMX Interface
Using the 75176 Transceiver

R — | — V_{DD}

R — Vᴅᴅ
RE — B
DE — A
D — GND

75176A
54M
A98161

75176

+5V

i Female XLR-5 conn.
Rear view

IO4 JIOO

100nF

100Ω

75176A
54M
A98161

⚠ Don't forget to connect all
the ground wires together!

111

DMX
Pinout

Female XLR–5 connector
Front view

DAT+ — 5
DMX2
DMX2
DAT– — 4
DAT+ — 3

1 — GND
2 — DAT–

Female XLR–3 conn.
Front view

DAT– — 2
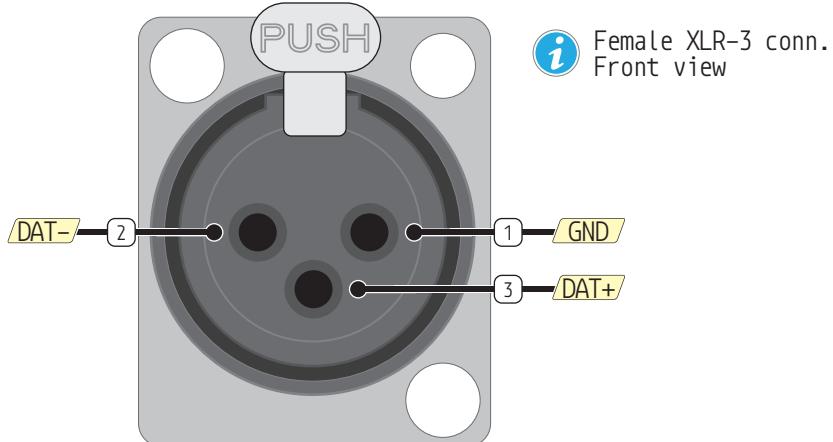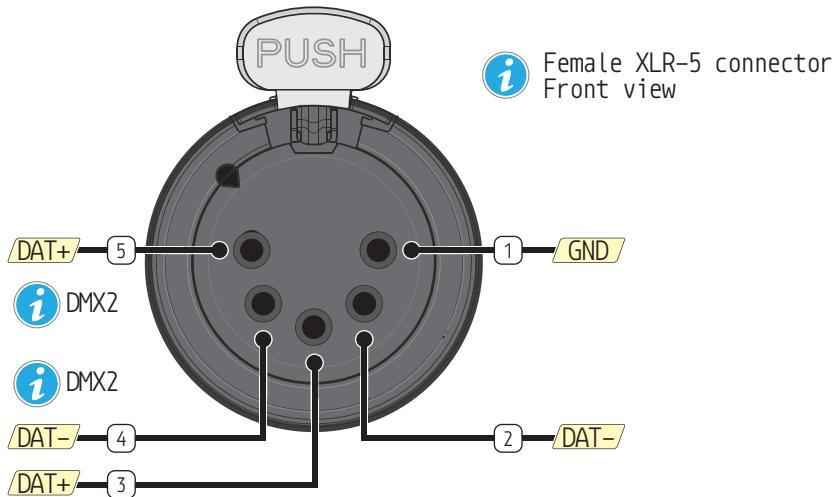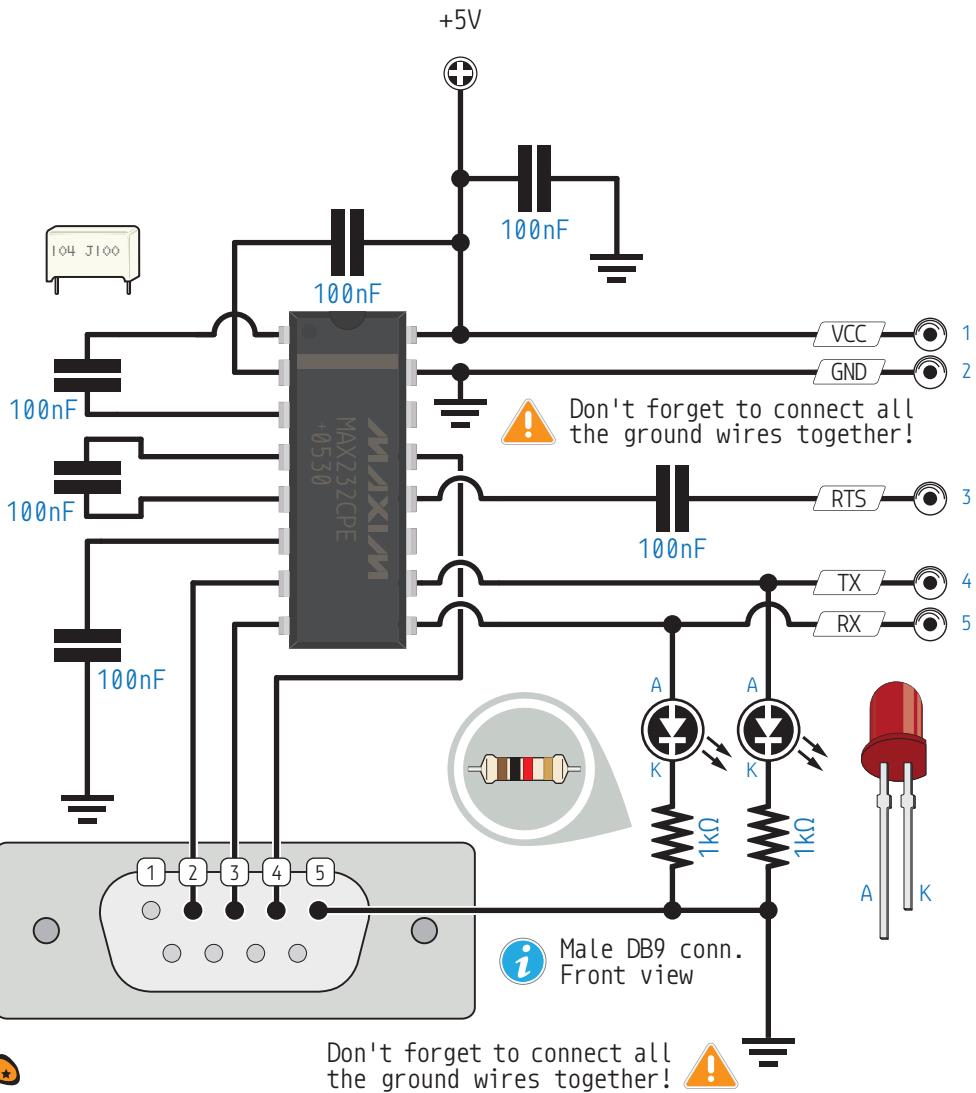
1 — GND
3 — DAT+

112
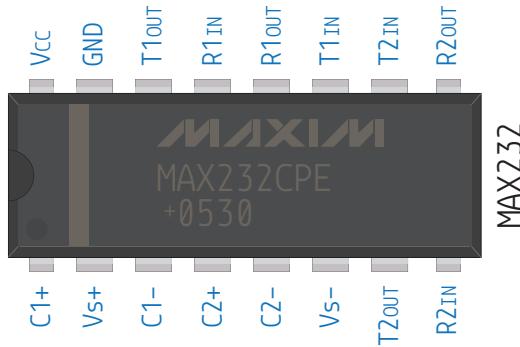
RS-232 Interface
Using the MAX232 RS-232 Driver

+5V

100nF

100nF

104 J100

100nF

100nF

MAX232CPE
+0530

100nF

VCC — 1

GND — 2

⚠️ Don't forget to connect all the ground wires together!

RTS — 3

100nF

TX — 4

RX — 5

A   A

K   K

1kΩ   1kΩ

A   K

1   2   3   4   5

ⓘ Male DB9 conn. Front view

Don't forget to connect all the ground wires together! ⚠️

RS-232

MAX232 Pinout

Vcc GND T1OUT R1IN R1OUT T1IN T2IN R2OUT

MAX232

MAXIM

MAX232CPE
+0530

C1+ Vs+ C1- C2+ C2- Vs- T2OUT R2IN

MAX232

RS-232 Pinout

3 TXD
DTR 4
2 RXD
GND 5
1 DCD

5 1
9

i Female DB9 conn.
Front view

RI 9
6 DSR
CTS 8
7 RTS

RS-232 is a standard for serial communication transmission of data. It was once a standard feature of a personal computer, but USB has displaced it from most of its peripheral interface roles mainly because of its low transmission speed. Nevertheless, RS-232 devices are still used, especially in industrial machines.
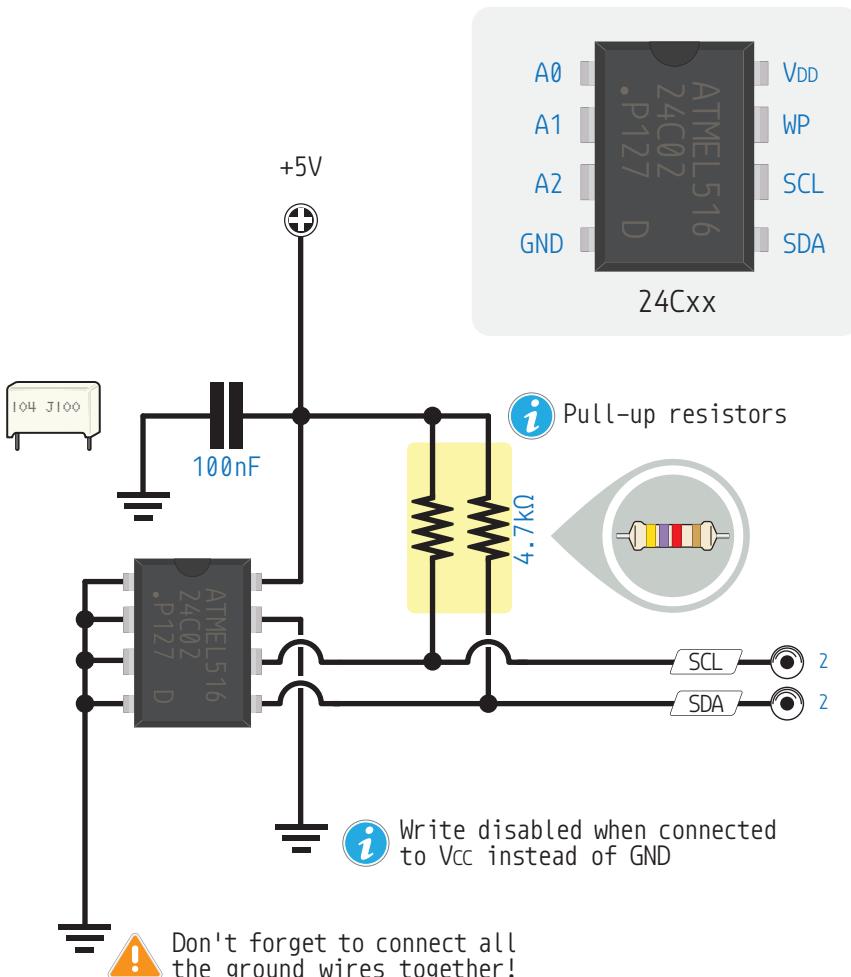
RTC
Using the DS1307 I²C RTC

DS1307

+5V

100nF

32,768kHz

i Pull-up resistors

4.7kΩ

DS1307
0219A4
022AD

3V

i If the backup battery is not in use connect V_BAT to GND

SCL 2

SDA 2

! Don't forget to connect all the ground wires together!

114
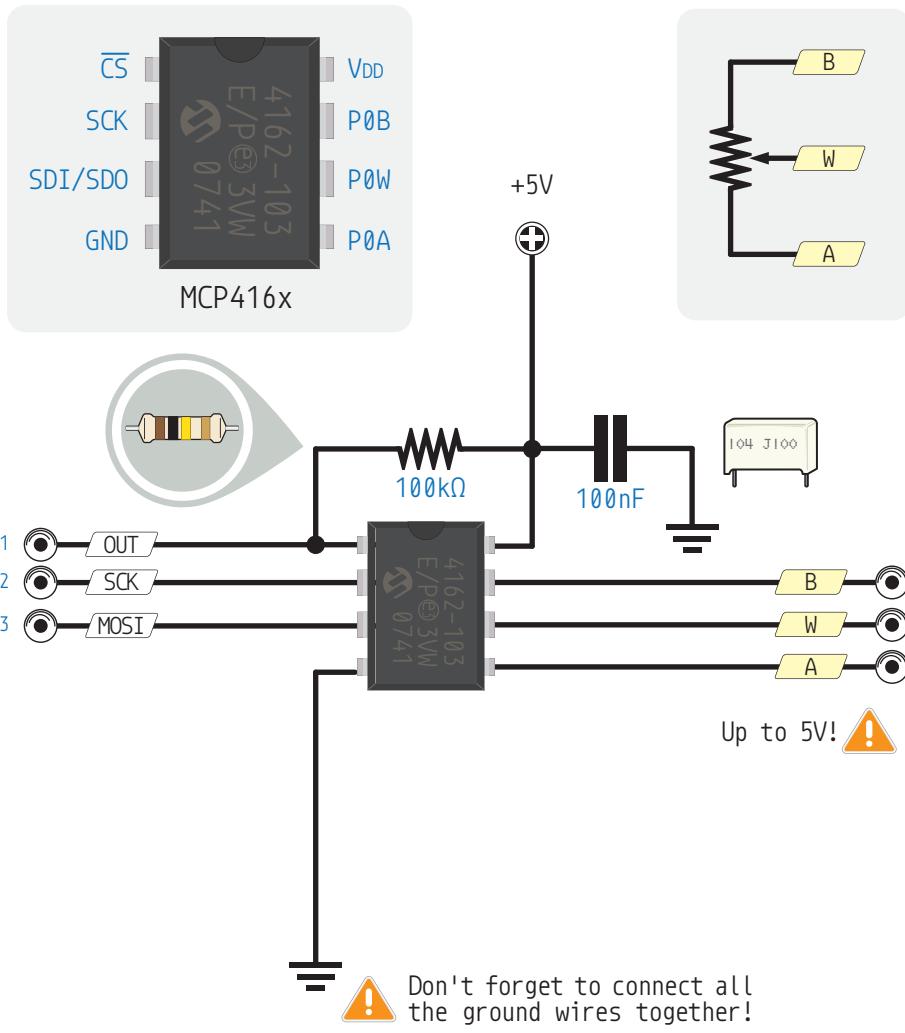
EEPROM
Using the 24Cxx Series EEPROM

24Cxx

A0	VDD
A1	WP
A2	SCL
GND	SDA

+5V

104 J100

100nF

ℹ Pull-up resistors

4.7kΩ

SCL 2

SDA 2

ℹ Write disabled when connected to Vcc instead of GND

⚠ Don't forget to connect all the ground wires together!

115

Digital Potentiometer
Using the MCP416x

CS
SCK
SDI/SDO
GND

V$_{DD}$
P0B
P0W
P0A

MCP416x

+5V

B
W
A

100kΩ

100nF

104 J100

1 OUT
2 SCK
3 MOSI

B
W
A

Up to 5V! ⚠

⚠ Don't forget to connect all
the ground wires together!
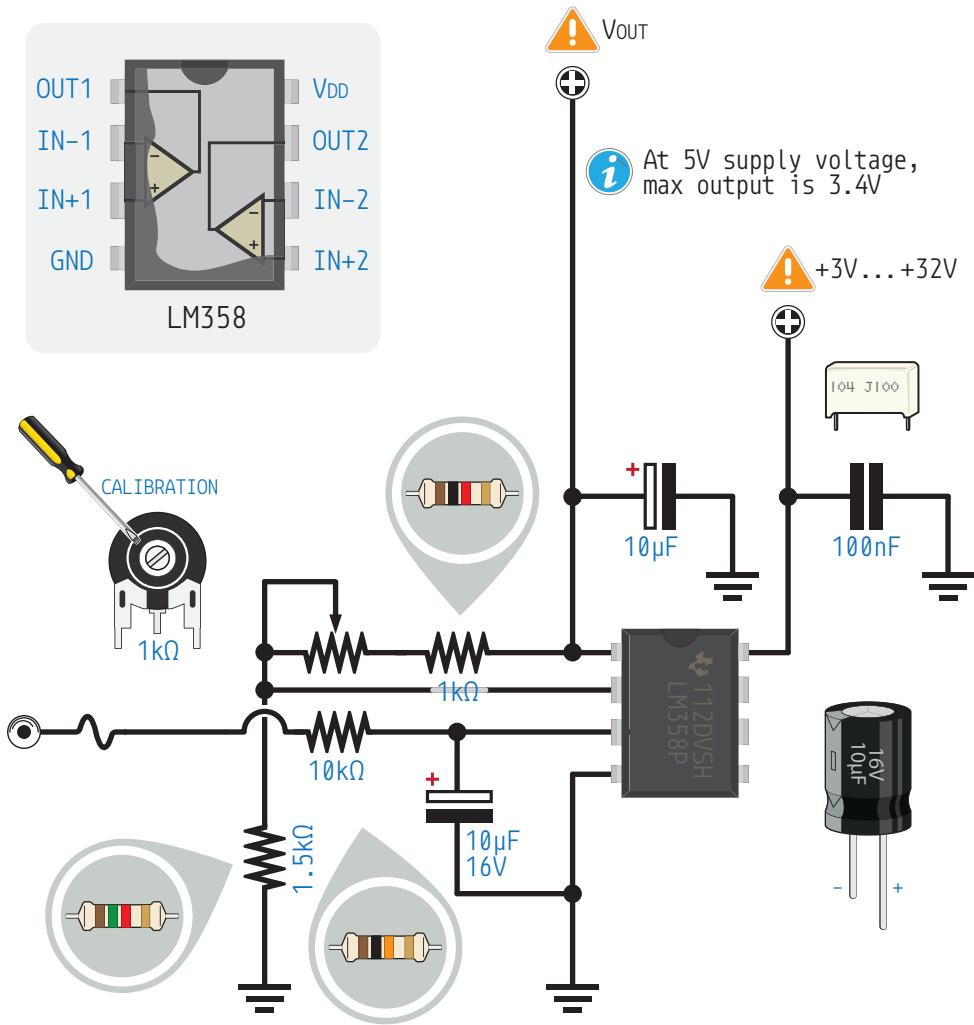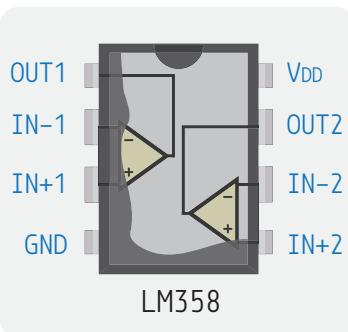
116

Buffer
Using the LM358

OUT1	V_DD
IN−1	OUT2
IN+1	IN−2
GND	IN+2

LM358

⚠ V_OUT

ⓘ At 5V supply voltage, max output is 3.4V

⚠ +3V...+32V

104 J100

+
10µF

100nF

CALIBRATION

1kΩ

1kΩ

10kΩ

+
10µF
16V

1.5kΩ

112DVSH
LM358P

16V
10µF

−   +

⚠ Don't forget to connect all the ground wires together!

117
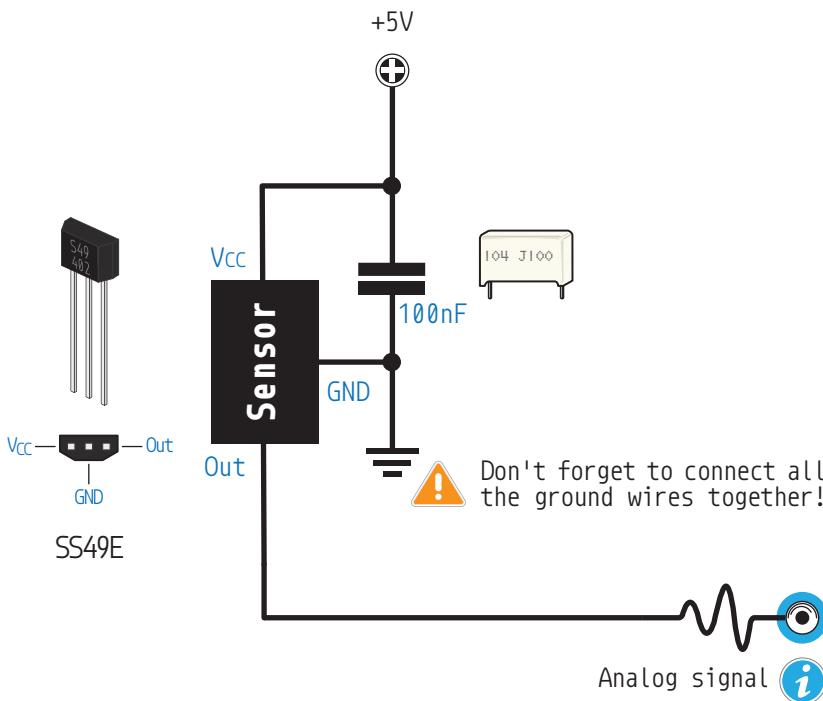
Hall Effect Sensor
Using the SS49E Hall Effect Sensor

+5V

Vcc

Sensor

100nF

104 J100

GND

Out

⚠️ Don't forget to connect all the ground wires together!

SS49E

Vcc —▪▪▪— Out

GND

Analog signal ℹ️

💡 A Hall effect sensosr are a transducesr that vary their output voltage in response to a magnetic field. The output voltage is set by the supply voltage and varies linearly in proportion to the strength of the magnetic field. They are used for proximity switching, positioning or speed detection.
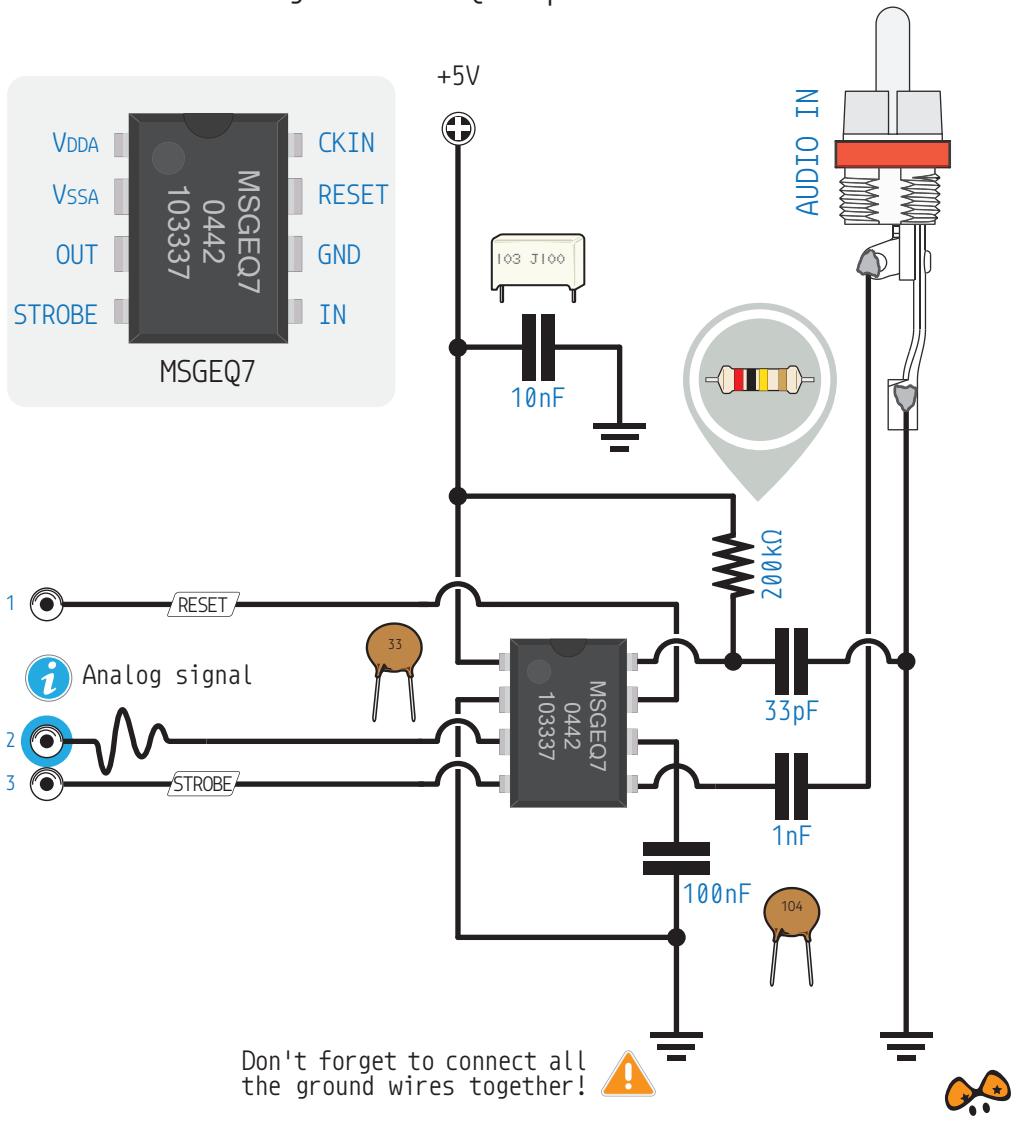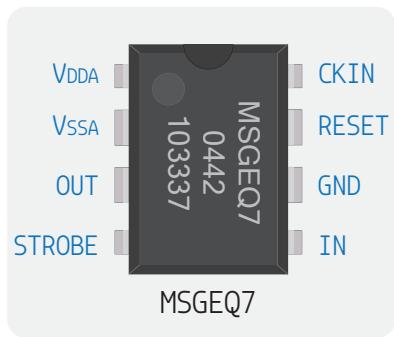
118
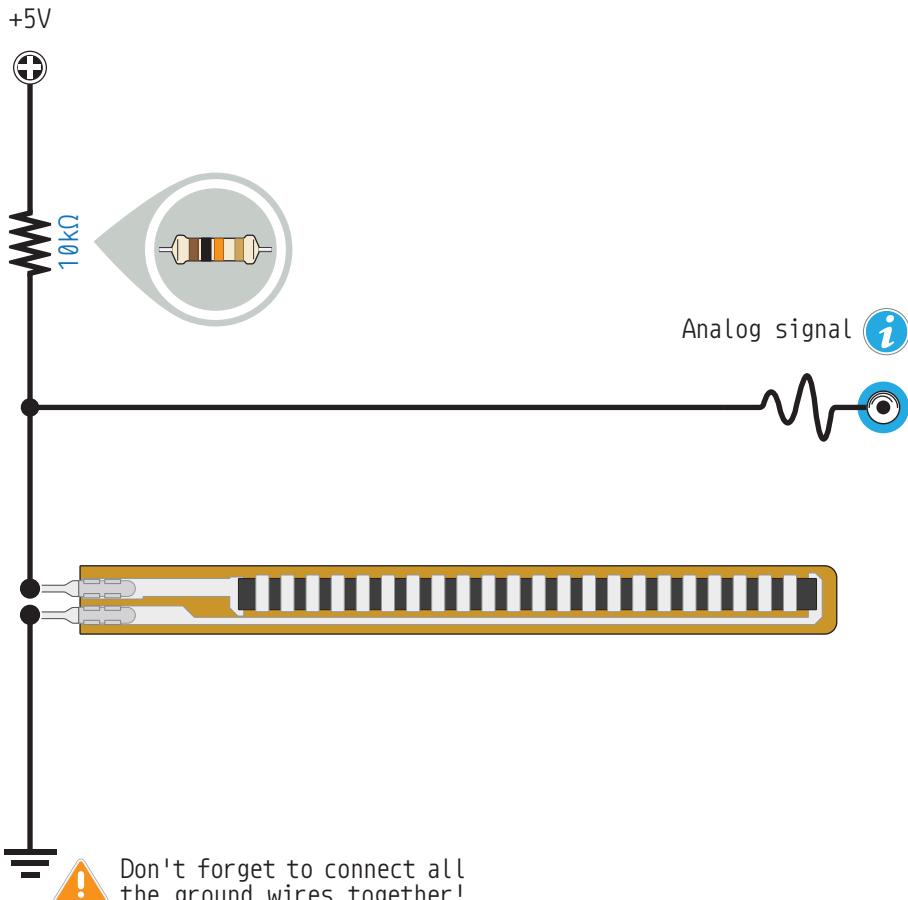
Spectrum Analyzer
Using the MSGEQ7 Equalizer

MSGEQ7

V_DDA	CKIN
V_SSA	RESET
OUT	GND
STROBE	IN

MSGEQ7
0442
103337

MSGEQ7

+5V

AUDIO IN

10nF

103 J100

200kΩ

1 RESET

Analog signal

33

MSGEQ7
0442
103337

33pF

2

3 STROBE

1nF

100nF

104

Don't forget to connect all
the ground wires together! ⚠

119

Flex Sensor
Basic Connections

+5V

10kΩ

Analog signal

Don't forget to connect all
the ground wires together!
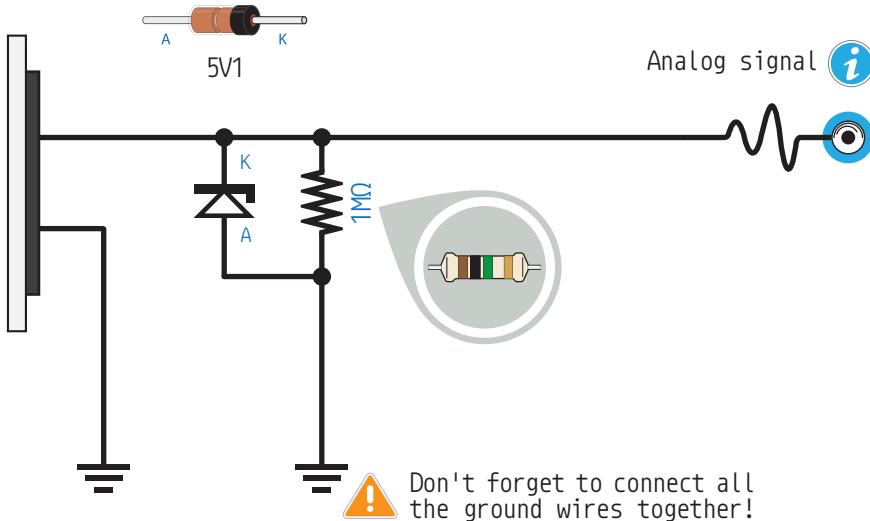
This flex sensor is a variable resistor whose resistance increases as the body
of the component bends. Sensors like these were used in the Nintendo Power Glove
and are patented technology of Spectra Symbol. Please be careful not to bend
them too much, especially at the base of the device, as they can get damaged.

Piezo Sensor
Basic Connections

A   K

5V1

K

A

1MΩ

Analog signal ⓘ

⚠ Don't forget to connect all
the ground wires together!
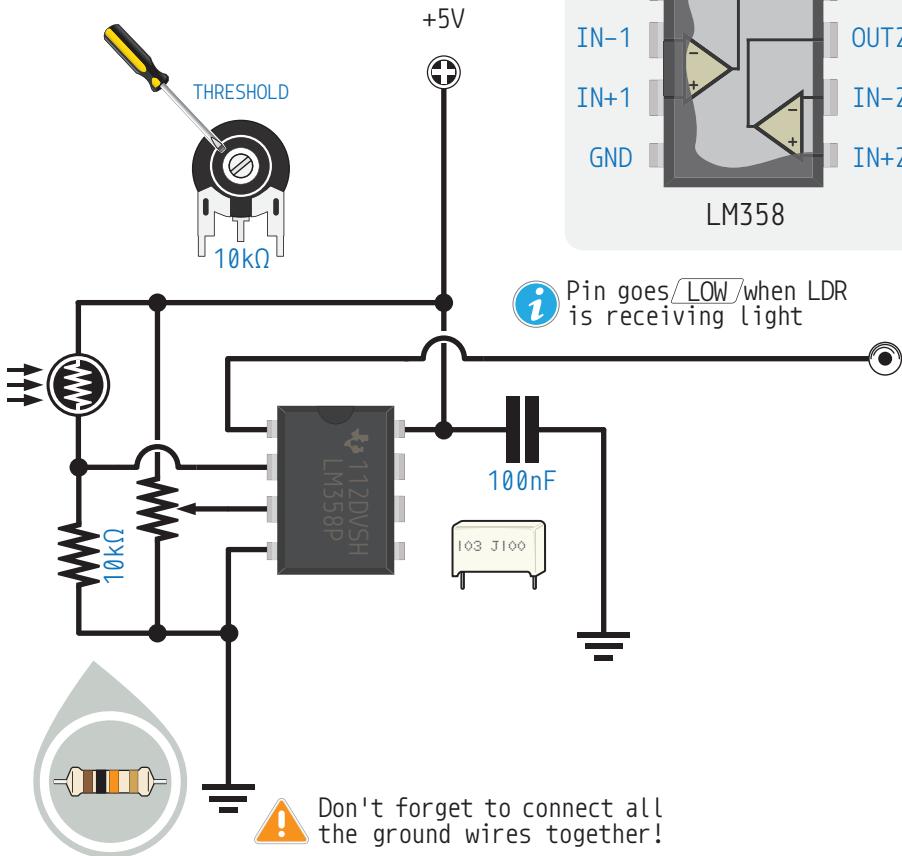
Piezoelectric sensors use the piezoelectric effect to measure changes in pressure, vibration, temperature, strain, or force and converted into a voltage. The piezoelectric effect is generally reversible and sensors can work also as output devices. If you open a piezo buzzer you can hack it into a piezo sensor.

121

Op-Amp Threshold Switch
Using the LM358 Op-Amp

+5V

THRESHOLD

10kΩ

OUT1		VDD
IN-1		OUT2
IN+1		IN-2
GND		IN+2

LM358

(i) Pin goes /LOW/ when LDR is receiving light

112DVSH
LM358P

100nF

I03 J100

10kΩ

⚠ Don't forget to connect all the ground wires together!
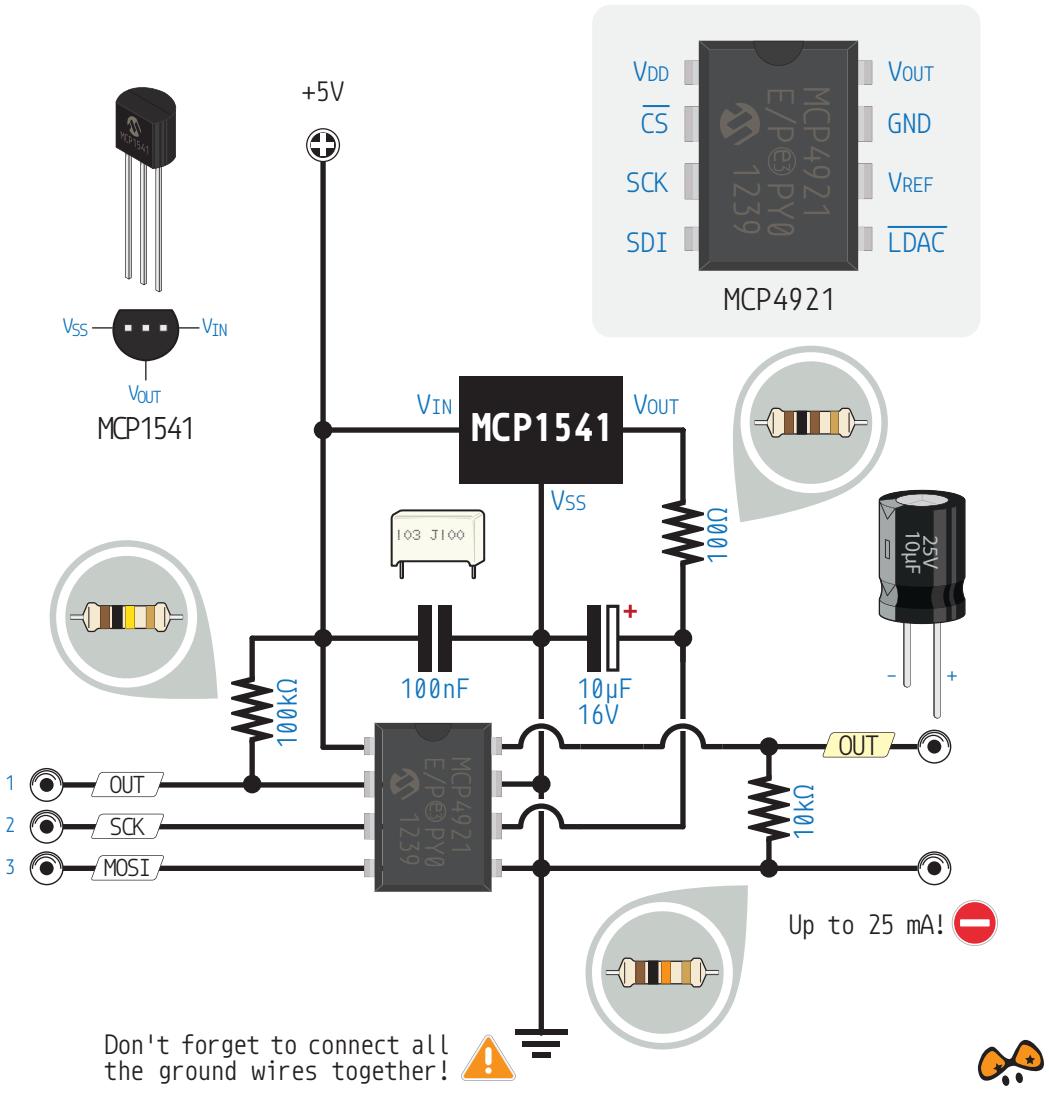
💡 The LM358 op-amp acts as a voltage comparator so you have to adjust the 10kΩ potentiometer for your desired activation treshold. You could replace the photo-resistor with any other resistive sensor!
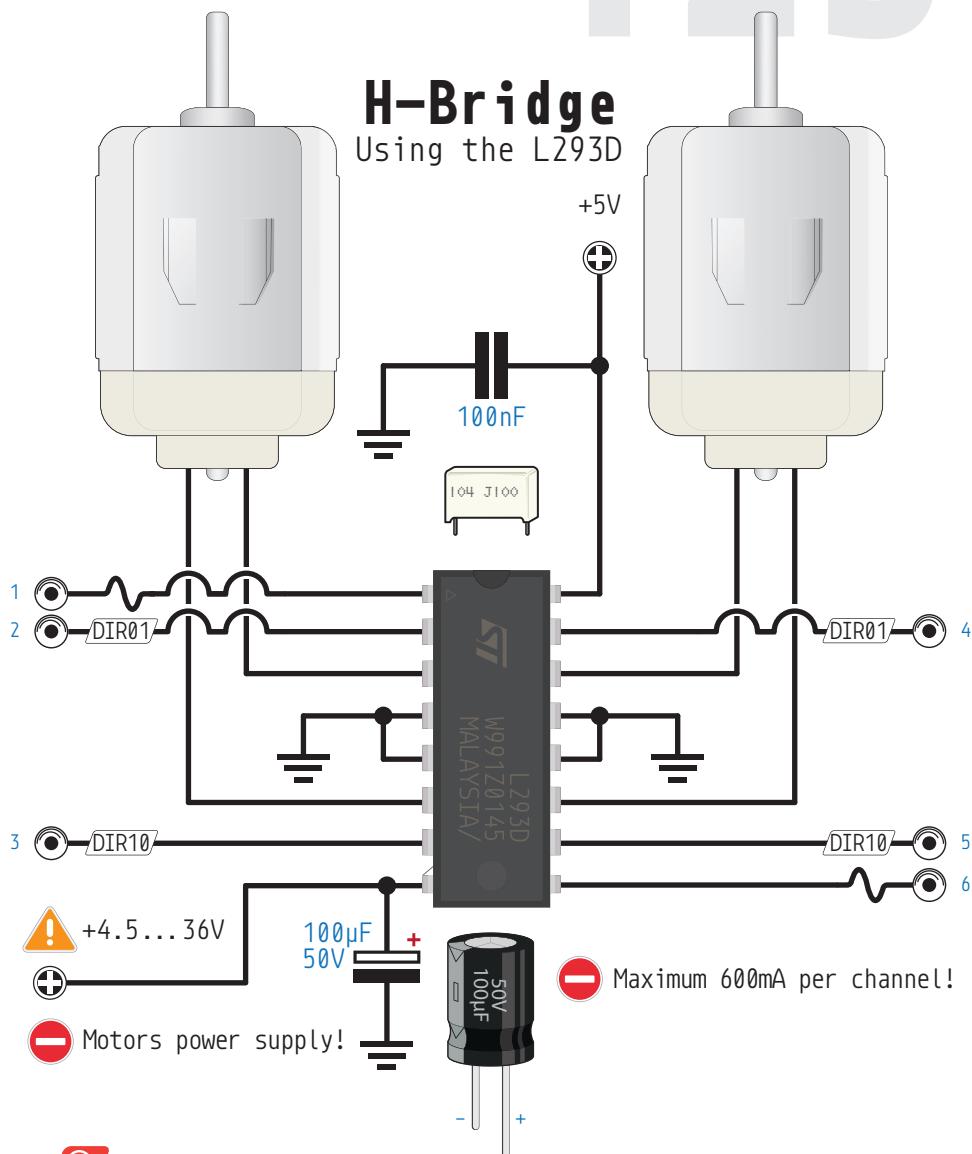
DAC
Using the MCP4921 12-Bit DAC

MCP4921

Vdd — Vout
CS — GND
SCK — Vref
SDI — LDAC

+5V

Vss — Vin
Vout

MCP1541

Vin MCP1541 Vout

Vss

103 J100

100Ω

25V 10µF

100kΩ

100nF

10µF 16V +

− +

1 OUT

2 SCK

3 MOSI

MCP4921 E/P@PY0 1239

OUT

10kΩ

Up to 25 mA! 🚫

Don't forget to connect all the ground wires together! ⚠️

123

H-Bridge
Using the L293D

+5V

100nF

104 J100

1
2 DIR01
DIR01 4

L293D
W991Z0145
MALAYSIA

3 DIR10
DIR10 5
6

⚠ +4.5...36V

100µF
50V

+

50V
100µF

⛔ Maximum 600mA per channel!

⛔ Motors power supply!

– +

💡 The L293D is a quadruple high-current half-H driver. It is designed to provide bidirectional drive currents of up to 600mA at voltages from 4.5V to 36V and it is able to drive inductive loads such as relays, solenoids, DC and bipolar stepper motors.
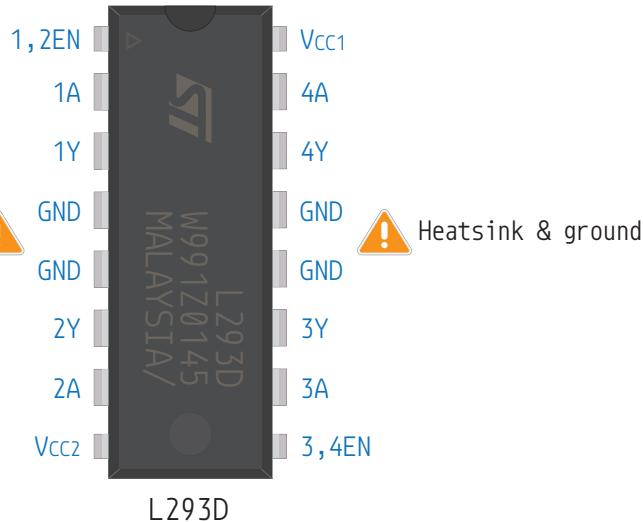
LD293D

Pinout

1,2EN	V$_{CC1}$
1A	4A
1Y	4Y
GND	GND
GND	GND
2Y	3Y
2A	3A
V$_{CC2}$	3,4EN

Heatsink & ground ⚠

⚠ Heatsink & ground

L293D

Function Table
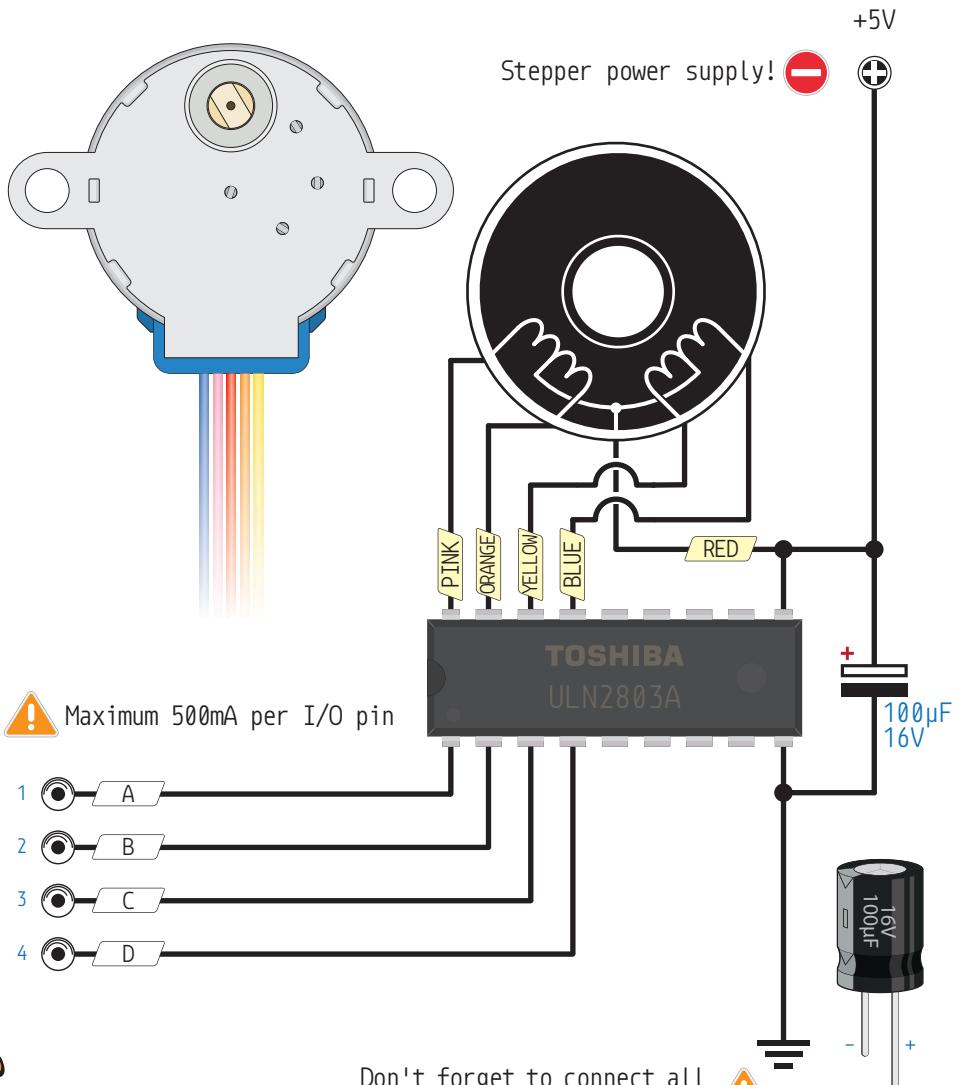
Unipolar Stepper Motor
Using the ULN2803 Darlington Transistor Array

+5V

Stepper power supply! 🚫 ⊕

PINK ORANGE YELLOW BLUE RED

TOSHIBA
ULN2803A

+
100µF
16V

⚠ Maximum 500mA per I/O pin

1 A
2 B
3 C
4 D

16V
100µF

– +

😎

Don't forget to connect all
the ground wires together! ⚠

124
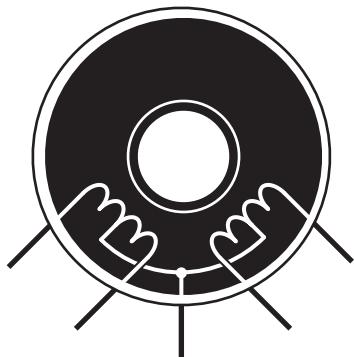
Stepper Motor
Basic Concepts
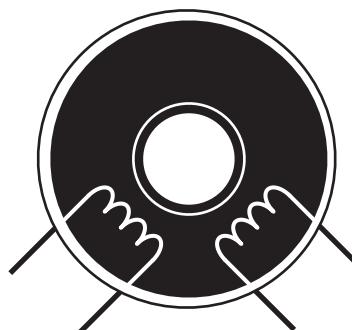
There exist two main types of stepper motors: unipolar and bipolar. In essence, they both work in the same way: electromagnets are turned on sequentially, causing the central motor shaft to turn. One difference between the two types is their voltage levels. **Unipolar** stepper motors operate only with positive voltages applied to the electromagnetic coils, e.g., 5V HIGH and 0V LOW. **Bipolar** stepper motors have two polarities: positive and negative, so their HIGH and LOW voltages would be, for

Unipolar stepper motor

instance, 2.5V and -2.5V respectively. This configuration requires H-bridge circuitry to reverse the current flow through the phases, producing the two polarities of the magnetic field. By energizing the phases with alternating the polarity, all the coils can be put to work turning the motor. Bipolar stepper motors have more torque because current flows through the entire coil, producing a stronger magnetic field to induce the shaft to rotate to the appropriate angle.
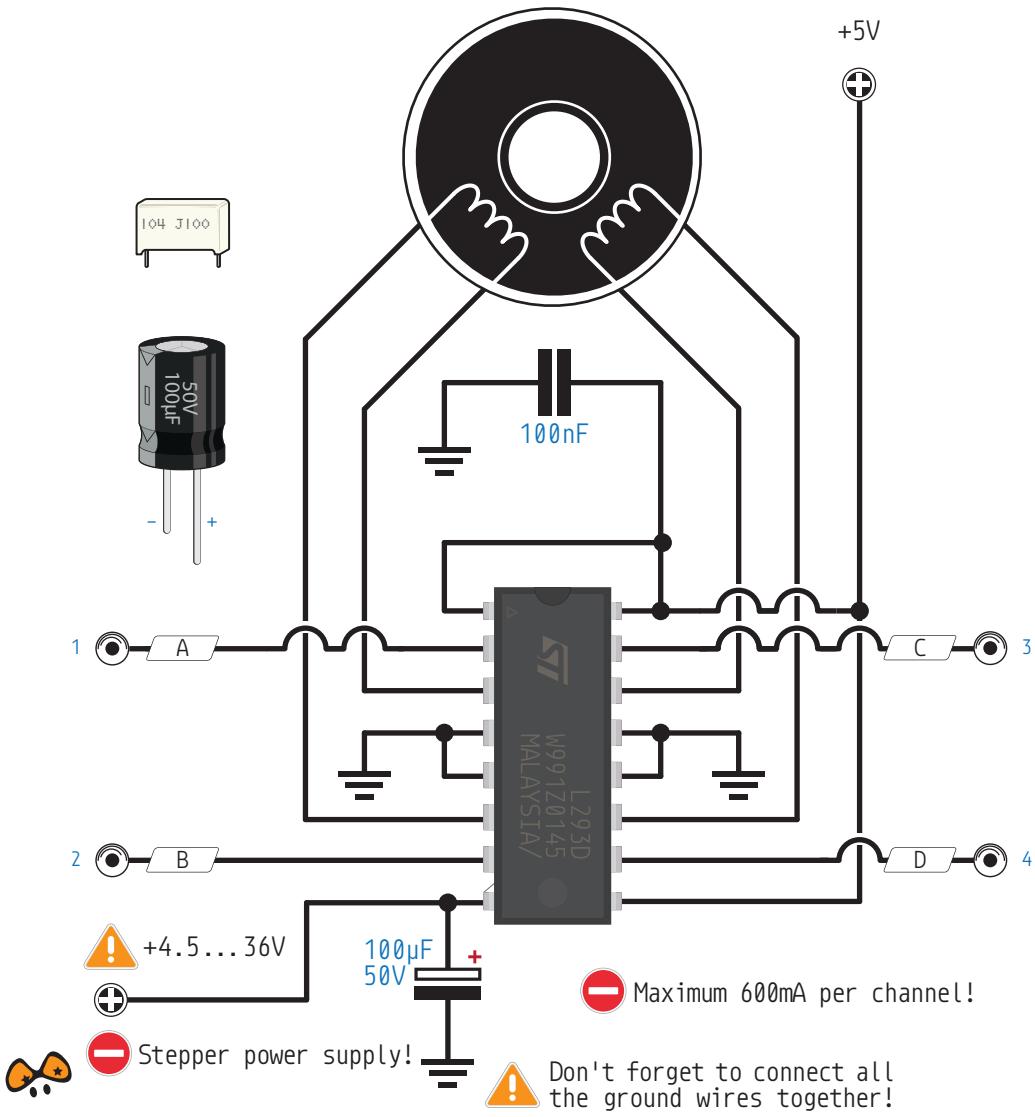
Bipolar stepper motor

Bipolar Stepper Motor
Using the L293D Motor Driver

+5V

104 J100

50V
100µF

−   +

100nF

1   A

2   B

C   3

D   4

L293D
W991Z0145
MALAYSIA/

⚠ +4.5...36V

100µF
50V   +

⛔ Maximum 600mA per channel!

⛔ Stepper power supply!

⚠ Don't forget to connect all
the ground wires together!

125

Bipolar Stepper Motor
Step Sequence

Full Step

A	B	C	D	Step
■			■	1
■	■			2
	■	■		3
		■	■	4

■ HIGH ☐ LOW

Stepper motors can be driven in two different patterns or sequences: full step sequence and half step sequence. In the full step sequence, two coils are energized at the same time and the motor shaft rotates. The order in which coils have to be energized is given in the table. In the half step sequence, the motor step angle is reduced in half, therefore the number of steps and the angular resolution are doubled. Half step mode is usually preffered over full step mode. The table shows the energizing pattern of the coils.

Half Step

A	B	C	D	Step
■			■	1
■				2
■	■			3
	■			4
	■	■		5
		■		6
		■	■	7
			■	8

■ HIGH ☐ LOW

Step Angle

The step angle of a stepper motor is defined as the angle traversed by the stepper motor in one step. To calculate step angle simply divide 360 by the number of steps that it takes the stepper motor to complete one revolution. In half step mode, the number of steps per revolution doubles.
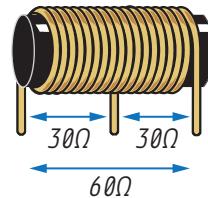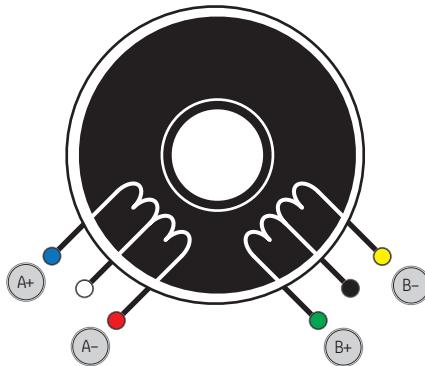
126
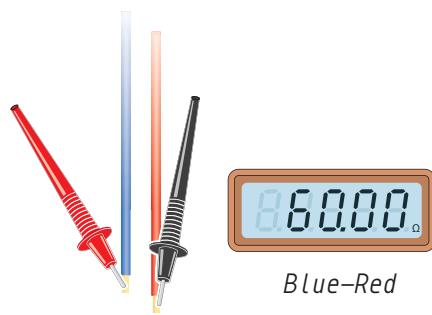
Stepper Motor
Phases

It's easy to identify which color corresponds to each phase inside the stepper motor, as well as the common terminals (A and B). We assume that each coil has a resistance of 30Ω.

30Ω 30Ω
60Ω
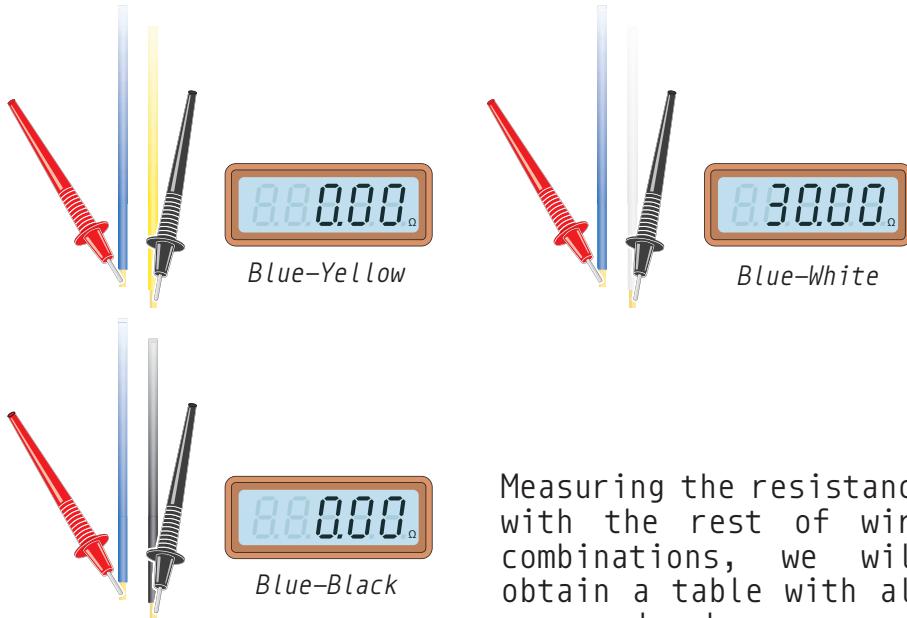
Use a multimeter and set it to the 200Ω range. Place the positive (+) terminal of the tester on a wire (e.g., blue) and with the negative terminal of the tester (-) begin measuring the resistance on all remaining wires.

Blue-Green

0.00 Ω

Blue-Red

60.00 Ω

Stepper Motor

Phases

Blue-Yellow

Blue-White

Blue-Black

Measuring the resistance with the rest of wire combinations, we will obtain a table with all measured values:
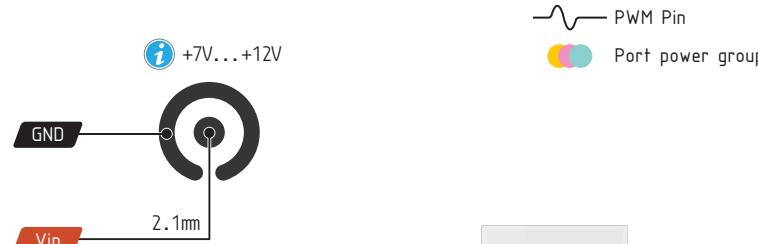
From these measurements it can be deduced that the connections are of this type:

	Blue	Green	Red	Yellow	White	Black
Blue		∞	60Ω	∞	30Ω	∞
Green	∞		∞	60Ω	∞	30Ω
Red	60Ω	∞		∞	30Ω	∞
Yellow	∞	60Ω	∞		∞	30Ω
White	30Ω	∞	30Ω	∞		∞
Black	∞	30Ω	∞	30Ω	∞	

Blue	Green	Red	Yellow	White	Black
A+	B+	A-	B-	A	B

B1

0-1.es/B1

UNO Pinout

+7V...+12V

GND

Vin

2.1mm

Input voltage to the board when it's using an external power supply. Not USB bus voltage! — Vin

Logic reference voltage for shields. Connected to the 5V bus — IOREF

PWM Pin

Port power group

Power	Serial PIN
GND	PIN Function
Physical PIN	Interrupt PIN
Port PIN	Control PIN
Analog PIN	IDE

⚠ **Absolute** MAX per pin 40mA, 20mA recommended

🚫 **Absolute** MAX 200mA for the entire package

🚫 The total current of each port power group **should not exceed** 100mA

NC

IOREF

RESET PCINT14 PC6 1

3V3

5V

GND

GND

Vin

14	A0	ADC0	PCINT8	PC0	23
15	A1	ADC1	PCINT9	PC1	24
16	A2	ADC2	PCINT10	PC2	25
17	A3	ADC3	PCINT11	PC3	26
18	A4	SDA ADC4	PCINT12	PC4	27
19	A5	SCL ADC5	PCINT13	PC5	28

IOREF
RESET
3V3
5V
GND
POWER
Vin

A0
A1
A2
A3
A4
A5
ANALOG IN

JP2
TX RX
L
AREF
GND

DIGITAL (PWM~)

13
12
~11
~10
~9
8

7
~6
~5
4
~3
2
TX→1
RX←0

ICSP

UNO
ON

28	PC5	PCINT13	ADC5	SCL		19	A5
27	PC4	PCINT12	ADC4	SDA		18	A4
21	AREF						
	GND						
19	PB5	PCINT5		SCK 💡		13	
18	PB4	PCINT4		MISO		12	
17	PB3	PCINT3	OC2A	MOSI		11	
16	PB2	PCINT2	OC1B	SS		10	
15	PB1	PCINT1	OC1A			9	
14	PB0	PCINT0	CLKO	ICP1		8	
13	PD7	PCINT23	AIN1			7	
12	PD6	PCINT22	AIN0	OC0A		6	
11	PD5	PCINT21	T1	OC0B		5	
6	PD4	PCINT20	XCK	T0		4	
5	PD3	PCINT19	INT1	OC2B		3	
4	PD2	PCINT18	INT0			2	
3	PD1	PCINT17		TXD		1	
2	PD0	PCINT16		RXD		0	

Connected to the ATmega and used for USB programming and comunicating with it

ICSP Pinout

RESET PCINT14 PC6 1

| 19 | PB5 | PCINT5 | SCK |
| 18 | PB4 | PCINT4 | MISO |

1

GND

5V

| 17 | PB3 | PCINT3 | OC2A | MOSI |

16U2 ICSP Pinout

RESET

| 3 | PB1 | PCINT1 | | SCK |
| 2 | PB3 | PCINT3 | PD0 | MISO |

1

GND

5V

| 16 | PB2 | PCINT2 | PDI | MOSI |

B2

0-1.es/B2

LEONARDO Pinout

PWM Pin
Port power group

Power		Serial PIN
GND		PIN Function
Physical PIN		Interrupt PIN
Port PIN		Control PIN
Analog PIN		IDE

+7V...+12V

GND

Vin

2.1mm

USB Connector
Micro Type B

⚠ **Absolute** MAX per pin
40mA, 20mA recommended

🚫 **Absolute** MAX 200mA
for the entire package

🚫 The total current of each
port power group **should
not exceed** 100mA

Input voltage to the board when it's using
an external power supply. Not USB bus voltage!

Vin

Logic reference voltage for shields
Connected to the 5V bus

IOREF

SCL		18	PD0	OC0B	INT0	SCL	3
SDA		19	PD1		INT1	SDA	2
AREF		42	AREF				
GND			GND				
~13		32	PC7	ICP3	OC4A	CLK0 💡	13
12		26	PD6	T1	OC4D	ADC9	12 A11
~11		12	PB7 PCINT7	OC1C	OC0A	RTS	11
~10		30	PB6 PCINT6	OC1B	OC4B	ADC13	10 A10
~9		29	PB5 PCINT5	OC1A	OC4B	ADC12	9 A9
8		28	PB4 PCINT4			ADC11	8 A8
7		1	PE6	AIN0	INT.6		7
~6		27	PD7	T0	OC4D	ADC10	6 A7
~5		31	PC6	OC3A	OC4A		5
4		25	PD4	ICPI		ADC8	4 A6
~3		18	PD0	OC0B	INT0	SCL	3
2		19	PD1		INT1	SDA	2
TX→1		21	PD3		INT3	TXD1	1
RX←0		20	PD2		INT2	RXD1	0

DIGITAL (PWM~)

POWER

IOREF
RESET
3.3V
5V
GND
Vin

NC	
IOREF	
RESET	13
3V3	
5V	
GND	
GND	
Vin	

LEONARDO

ANALOG IN

A0	
A1	
A2	
A3	
A4	
A5	
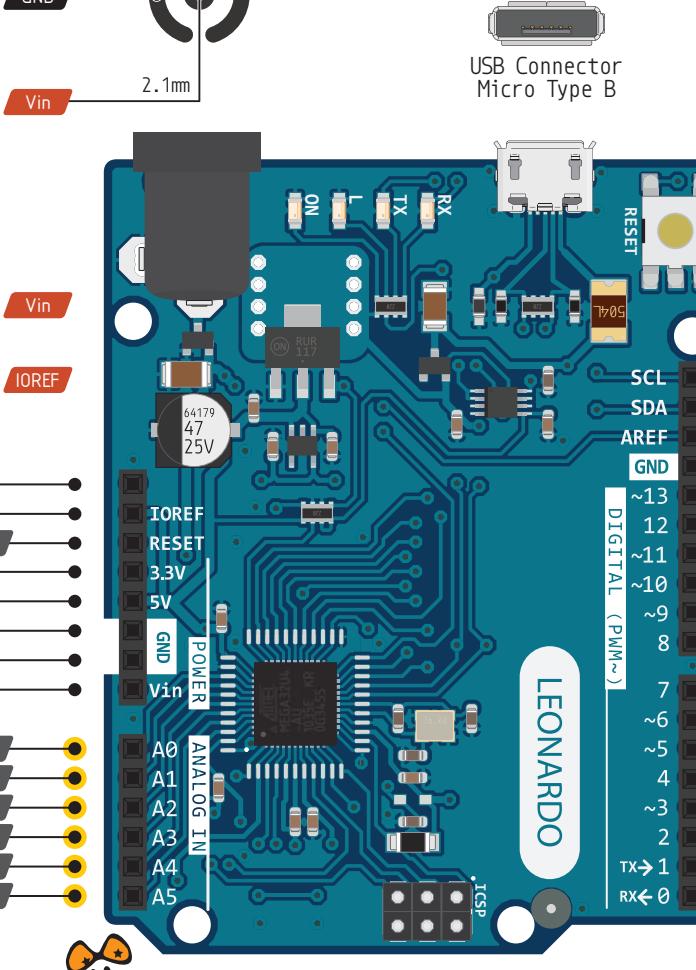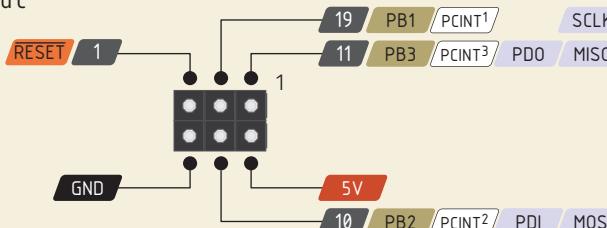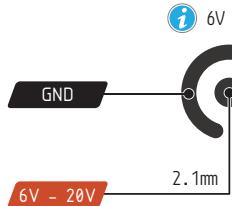
18	A0	ADC7	TDI	PF7	36
19	A1	ADC6	TDO	PF6	37
20	A2	ADC5	TMS	PF5	38
21	A3	ADC4	TCK	PF4	39
22	A4	ADC1		PF1	40
23	A5	ADC0		PF0	41

ICSP

ICSP Pinout

		19	PB1 PCINT1	SCLK
RESET	1	11	PB3 PCINT3	PD0 MISO

1

GND			
5V			
	10	PB2 PCINT2	PDI MOSI

B3

0-1.es/B3

FLUO WiFi Pinout

6V – 20V

GND

6V – 20V

2.1mm

USB Connector
Micro Type B

ESP-32 Gateway

24	PC5	PCINT21	TDI	RX5
23	PC4	PCINT20	TDO	TX5
30	PA7	PCINT7	ADC7	ATMEGINT

	Power		Serial PIN
	GND		PIN Function
	Physical PIN		Interrupt PIN
	Port PIN		Control PIN
	Analog PIN		IDE

PWM Pin

AP RESET

RESET

ON
RST
RX
TX

RSET
STATUS
LINK
BLE
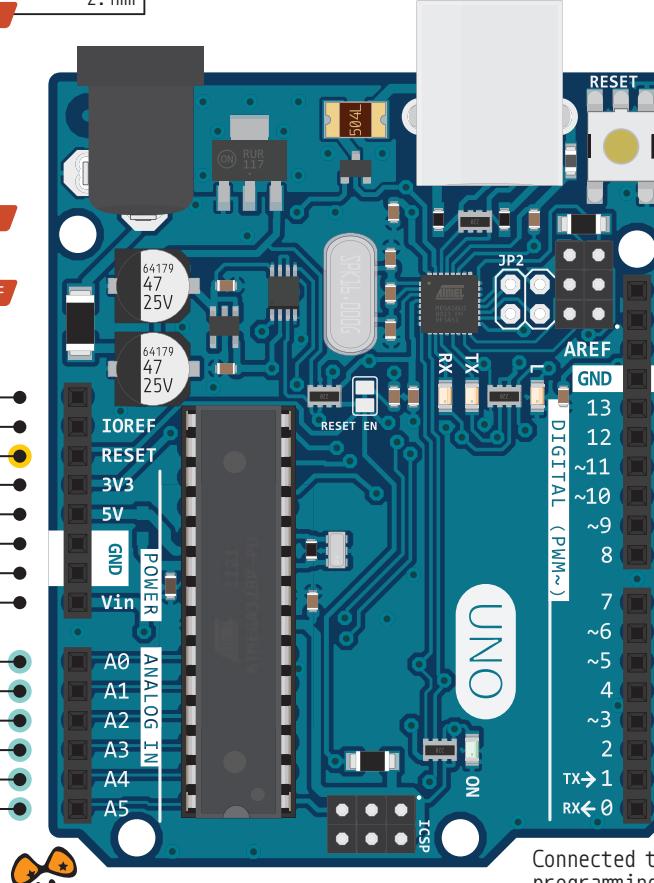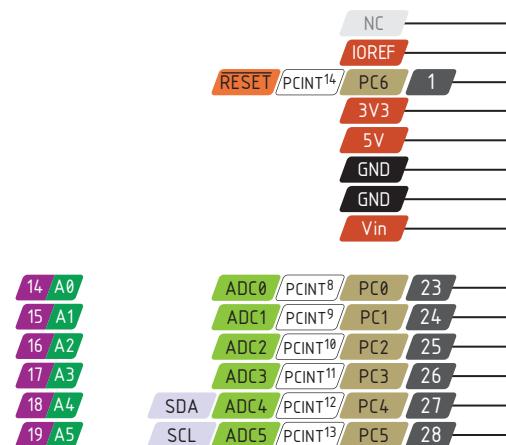CLOUD

Input voltage to the board when it's using an external power supply. Not USB bus voltage!   Vin
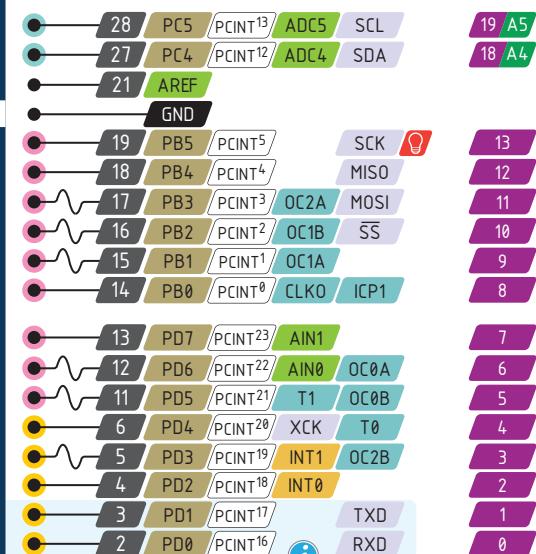
Logic reference voltage for shields Connected to the 5V bus   IOREF
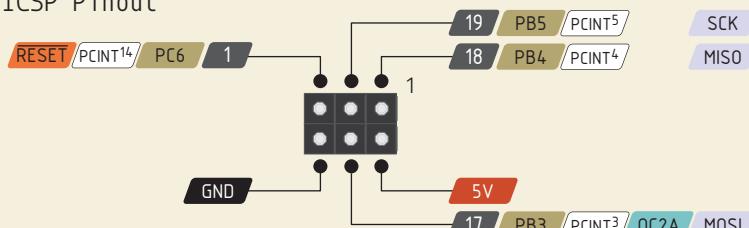
Absolute MAX per pin 40mA, 20mA recommended

Absolute MAX 200mA for the entire package

GPIO pins rated at 5V

6-20V

AP-RST

ESP-WROOM-32

Touch test

SDA
SCL
AREF
GND
13
12
11
10
9
8

19	PC0	PCINT16	SCL		16
20	PC1	PCINT17	SDA		17
		AREF			
		GND			
41	PB1	PCINT9	CLKO	T1	1
40	PB0	PCINT8	XCK0	T0	0
43	PB3	PCINT11	OC0A	AIN1	3
44	PB4	PCINT12	OC0B	SS̄ SS	4
16	PD7	PCINT31	OC2A		15
42	PB2	PCINT10	INT2	AIN0	2

The maximum reccomended current you can draw is 750mA for 3.3V and 750mA for 5V

| NC |
| IOREF |
| RESET |
| 3V3 |
| 5V |
| GND |
| GND |
| VIN |

RFU
IOREF
RESET
3.3V
5V
GND
GND
VIN

DIGITAL

FLUO Wi-Fi

26	A5
27	A4
28	A3
29	A2
30	A1
31	A0

ADC5	PCINT5	PA5	32
ADC4	PCINT4	PA4	33
ADC3	PCINT3	PA3	34
ADC2	PCINT2	PA2	35
ADC1	PCINT1	PA1	36
ADC0	PCINT0	PA0	37

A0
A1
A2
A3
A4
A5

ANALOG IN

SD CARD

ICSP

7
6
5
4
3
2
TX -> 1
RX <-0

25	PC6	PCINT23	TOSC1		22
15	PD6	PCINT30	OC2B	ICP1	14
14	PD5	PCINT29	OC1A		13
12	PD3	PCINT27	INT1	TXD1	11
13	PD4	PCINT28	OC1B	XCK1	12
11	PD2	PCINT26	INT0	RXD1	10
10	PD1	PCINT25		TXD0	9
9	PD0	PCINT24		RXD0	8

microSD

Connected to the ATmega and used for USB programming and comunicating with it

ICSP Pinout

RESET

| 3 | PB7 | PCINT15 | SCK |
| 2 | PB6 | PCINT14 | MISO |

1

GND

| 1 | PB5 | PCINT13 | MOSI |

5V

16U2 ICSP Pinout

RESET

| 3 | PB1 | PCINT1 | | SCK |
| 2 | PB3 | PCINT3 | PD0 | MISO |

1

GND

| 16 | PB2 | PCINT2 | PDI | MOSI |

5V

B4

0-1.es/B4

Nano Pinout

〰 PWM Pin

🔴🟡 Port power group

🟥 Power	🟦 Serial PIN
⬛ GND	🟦 PIN Function
⬛ Physical PIN	🟦 Interrupt PIN
🟫 Port PIN	🟧 Control PIN
🟩 Analog PIN	🟪 IDE

1	TXD	PCINT17	PD1	31	🟡
0	RXD	PCINT16	PD0	30	●
	RESET	PCINT14	PC6	29	●
			GND		●
2	INT0	PCINT18	PD2	32	🟡
3	OC2B INT1	PCINT19	PD3	1	🟡〰
4	T0 XCK	PCINT20	PD4	2	🟡
5	T1 OC0B	PCINT21	PD5	9	🔴〰
6	OC0A AIN0	PCINT22	PD6	10	🔴〰
7	AIN1	PCINT23	PD7	11	🔴
8	ICP1 CLKO	PCINT20	PB0	12	🔴
9	OC1A	PCINT1	PB1	13	🔴〰
10	S̄S̄ OC1B	PCINT2	PB2	14	🔴〰
11	MOSI OC2	PCINT3	PB3	15	🔴〰
12	MISO	PCINT4	PB4	16	🔴

NANO

TX RX ON L
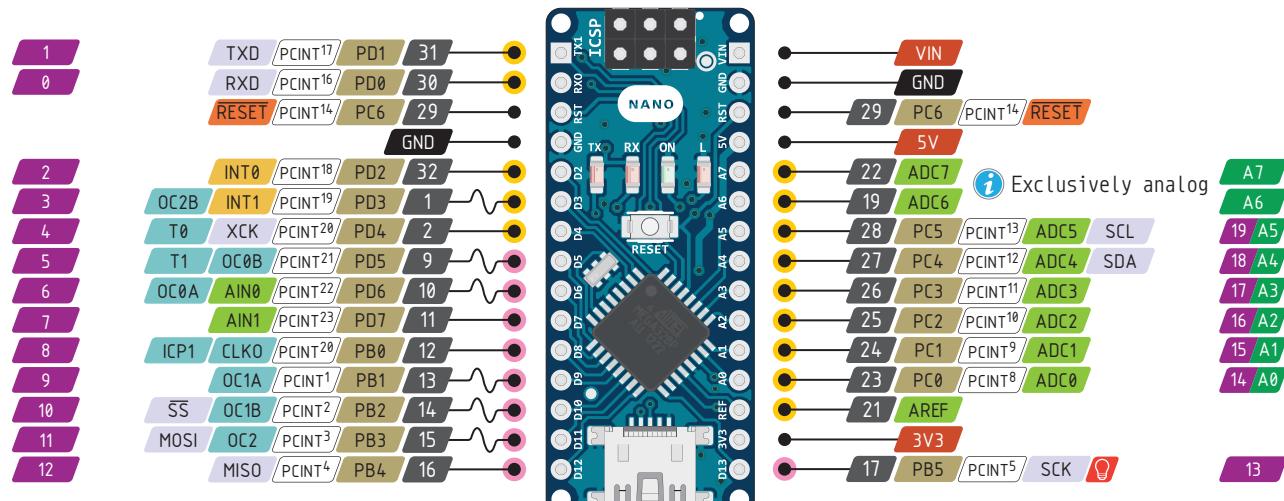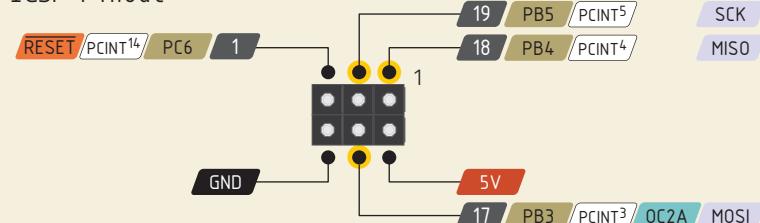
RESET

USB Connector
Mini Type B

			VIN		
			GND		
29	PC6	PCINT14	RESET		●
			5V		●
22	ADC7			A7	🟡
19	ADC6			A6	🟡
28	PC5	PCINT13	ADC5	SCL	19 A5 🟡
27	PC4	PCINT12	ADC4	SDA	18 A4 🟡
26	PC3	PCINT11	ADC3		17 A3 🟡
25	PC2	PCINT10	ADC2		16 A2 🟡
24	PC1	PCINT9	ADC1		15 A1 🟡
23	PC0	PCINT8	ADC0		14 A0 🟡
21	AREF				🟡
	3V3				
17	PB5	PCINT5	SCK	💡	🔴
					13

ℹ️ Exclusively analog

ICSP Pinout

19	PB5	PCINT5		SCK
18	PB4	PCINT4		MISO
RESET	PCINT14	PC6	1	
			1	
GND				
			5V	
17	PB3	PCINT3	OC2A	MOSI

VIN — Input voltage to the board when it's using an external power supply. Not USB bus voltage!

⚠️ Absolute MAX per pin
40mA, 20mA recommended

🚫 Absolute MAX 200mA
for the entire package

🚫 The total current of each port power group should not exceed 100mA

NodeMCU Pinout

	Power		Serial PIN
	GND		PIN Function
	Physical PIN		Interrupt PIN
	Port PIN		Control PIN
	Analog PIN		

⎓ PWM Pin

Vin USB bus voltage

A0

TOUT ADC 2
RESERVED
RESERVED
SD D3 SD D3 IO10 12
SD D2 IO9 11
MOSI SD D1 IO8 13
CS SD D1 IO11 9
MISO SD CMD IO7 10
CLK SD CLK IO6 14
GND
3V3
Also known as CHPD ⓘ EN 1
RESET 3
GND
Vin

4 IO16 WAKE
20 IO5
19 IO4
18 IO0 CS2
17 IO2 TXD1
3V3
GND
5 IO14 HSPI CLK CLK
6 IO12 HSPI Q HMISO
7 IO13 HSPI D RXD2 CTS0 HMOSI
16 IO15 HSPI CS TXD2 RTS0
21 IO3 RXD0
22 IO1 TXD0 CS1
GND
3V3

0
1
2
3 ⓘ LOW → firmware flashing
4   HIGH → normal boot

5
6
7
8
9
10

RST   FLASH

RESET   FLASH

USB Connector
Micro Type B

B6

0-1.es/B6

ESP-WROOM-32 Pinout

Legend:

Power	GND	Serial PIN	PIN Function
Physical PIN	Port PIN	Interrupt PIN	Control PIN
Analog PIN	Touch Pin	IDE	DAC Pin

PWM Pin

⚠️ **Absolute** MAX per pin
12mA, 6mA recommended

Chip Enable. High: (High: ON, Low: OFF – minimum power) Never leave CHIP^PU floating! ⚠️

Left side (top to bottom):

	GND
	3.3V
CHIP^PU	9
ADC^PA RTCIO⁰ ADC1_0 SENS^VP IO36	5
ADC^PA RTCIO³ ADC1_3 SENS^VN IO39	8
RTCIO⁴ ADC1_6 VDET¹ IO34	10
RTCIO⁵ ADC1_7 VDET² IO35	11
XTAL³² TOUCH⁹ RTCIO⁹ ADC1_4 IO32	12
XTAL³² TOUCH⁸ RTCIO⁸ ADC1_5 IO33	13
DAC_1 RTCIO⁶ ADC2_8 EMAC^RXD0 IO25	14
DAC_2 RTCIO⁷ ADC2_9 EMAC^RXD1 IO26	15
TOUCH⁷ RTCIO¹⁷ ADC2_7 EMAC^RXDV IO27	16
HS2^CLK SD^CLK HSPI^CLK MT^MS TOUCH⁶ RTCIO¹⁶ ADC2_6 EMAC^TXD2 IO14	17
HS2^DATA2 SD^DATA2 HSPI^Q MT^DI TOUCH⁵ RTCIO¹⁵ ADC2_5 EMAC^TXD3 IO12	18

Right side (top to bottom):

	GND
36 IO23	VSPI^D HS1^STROBE
39 IO22 EMAC^TXD1 U0^RTS VSPI^WP
41 IO1 EMAC^TXD2 U0^TXD CLK^OUT3	ℹ️ Programming Port
40 IO3 U0^RXD CLK^OUT2
42 IO21 EMAC^TXEN VSPI^HD
NC
38 IO19 EMAC^TXD0 U0^CTS VSPI^Q
35 IO18 VSPI^CLK HS1^DATA7
34 IO5 EMAC^RXCLK VSPI^CS0 HS1^DATA6
27 IO17 EMAC^CO180 U2^TDX HS1^DATA5
25 IO16 EMAC^CLKOUT U2^RDX HS1^DATA4
24 IO4 EMAC^TXER ADC2_0 RTCIO¹⁰ TOUCH⁰ HSPI^HD SD^DATA1 HS2^DATA1
23 IO0 EMAC^TXCLK ADC2_1 RTCIO¹¹ TOUCH¹ CLK^OUT1

Bottom (left):

	GND
HS2^DATA3 SD^DATA3 HSPI^D MT^CK TOUCH⁴ RTCIO¹⁴ ADC2_4 EMAC^RXER IO13	20
SD^DATA2 HS1^DATA2 U1^RXD SPI^HD IO9	28
SD^DATA3 HS1^DATA3 U1^TXD SPI^WP IO10	29
SD^CMD HS1^CMD U1^RTS SPI^CS0 IO11	30

Bottom (right):

22 IO2 HSPI^WP ADC2_2 RTCIO¹² TOUCH²
21 IO15 EMAC^RXD3 ADC2_3 RTCIO¹³ TOUCH³ MT^D0 HSPI^CS0 SD^CMD HS2^CMD
33 IO8 SPI^D U2^CTS HS1^DATA1 SD^DATA1
32 IO7 SPI^Q U2^RTS HS1^DATA0 SD^DATA0
31 IO6 SPI^CLK U1^CTS HS1^CLK SD^CLK

ESP-WROOM-32

B7

0-1.es/B7

DIY Microcontroller Board
Basic Connections

Use the ICSP port to burn the bootloader
Use the FTDI port to upload the sketch

⚠️ Absolute MAX per pin
40mA, 20mA recommended

🚫 Absolute MAX per pin 200mA
for the entire package

🚫 The total current of each port
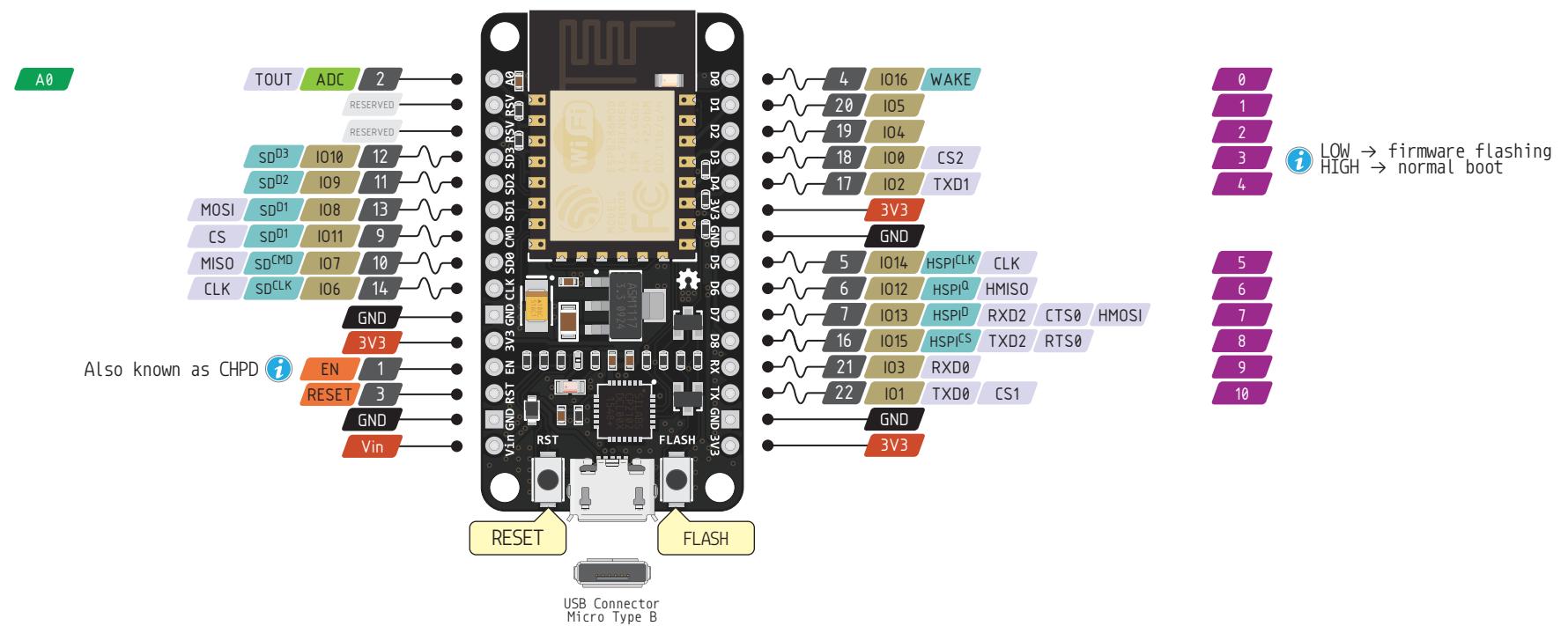power group should not exceed 100mA

ICSP Connections

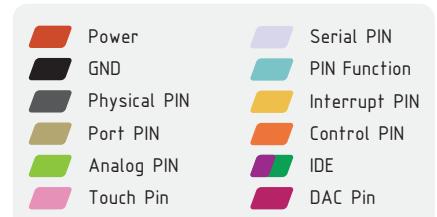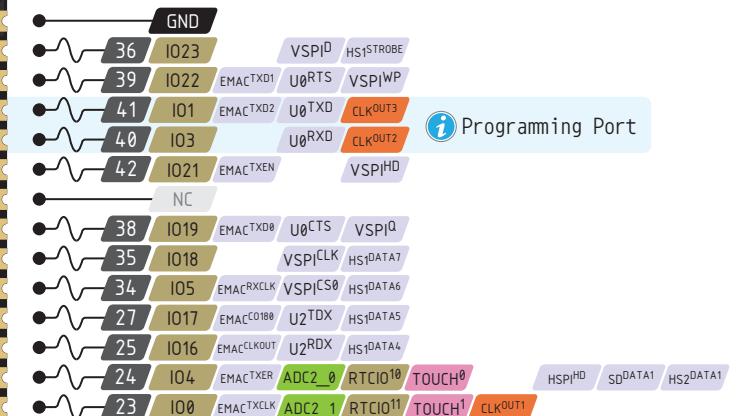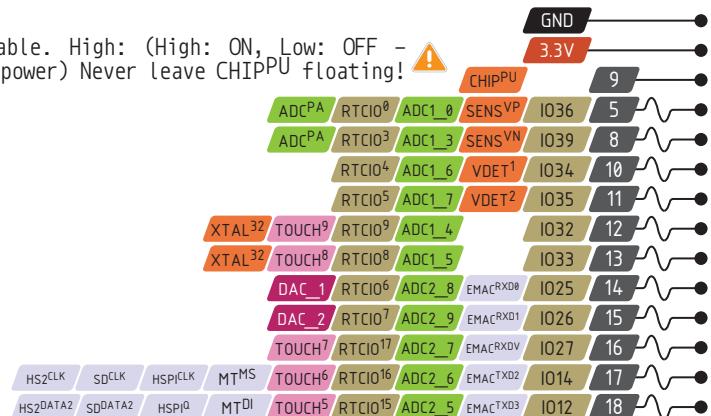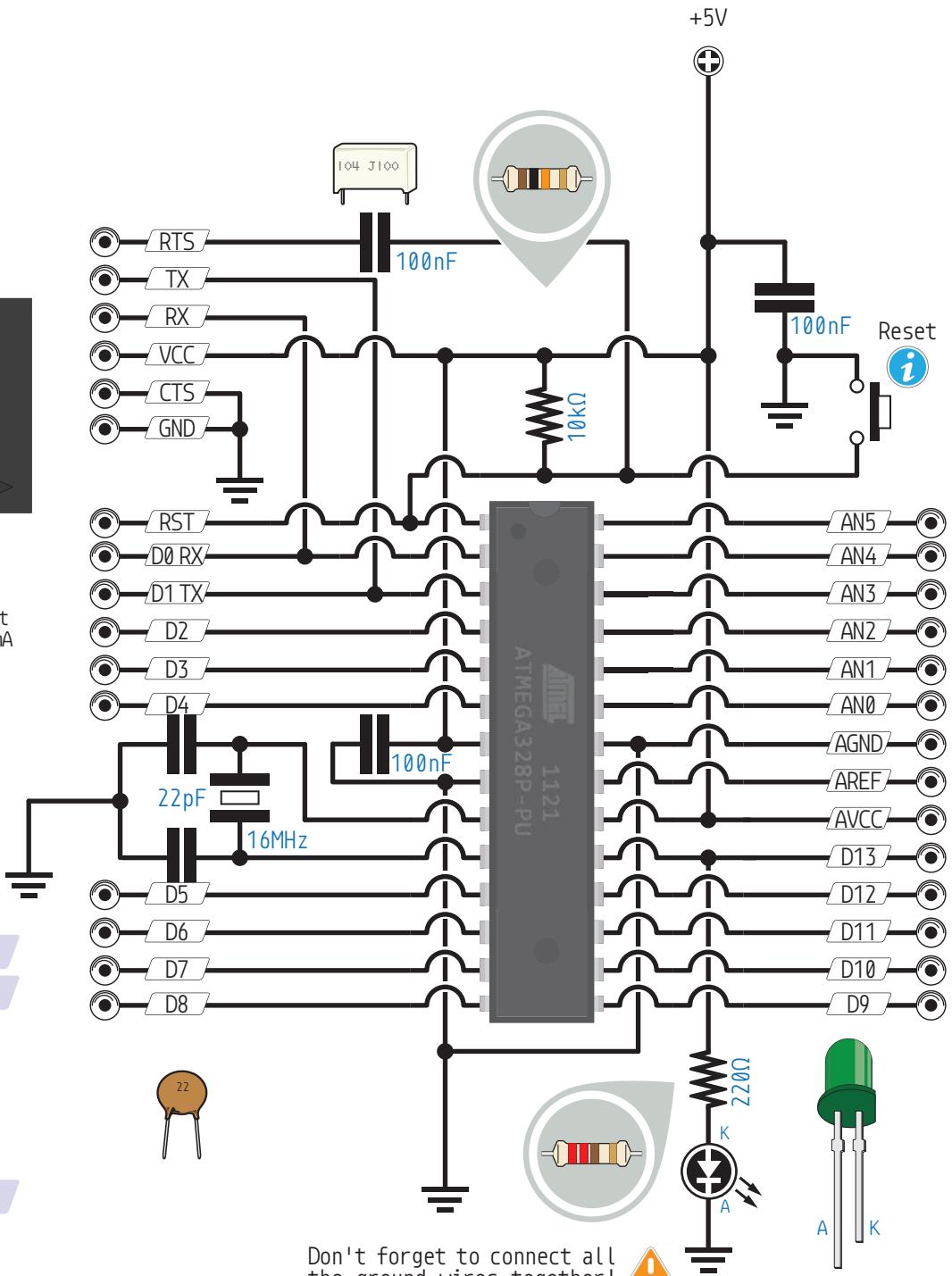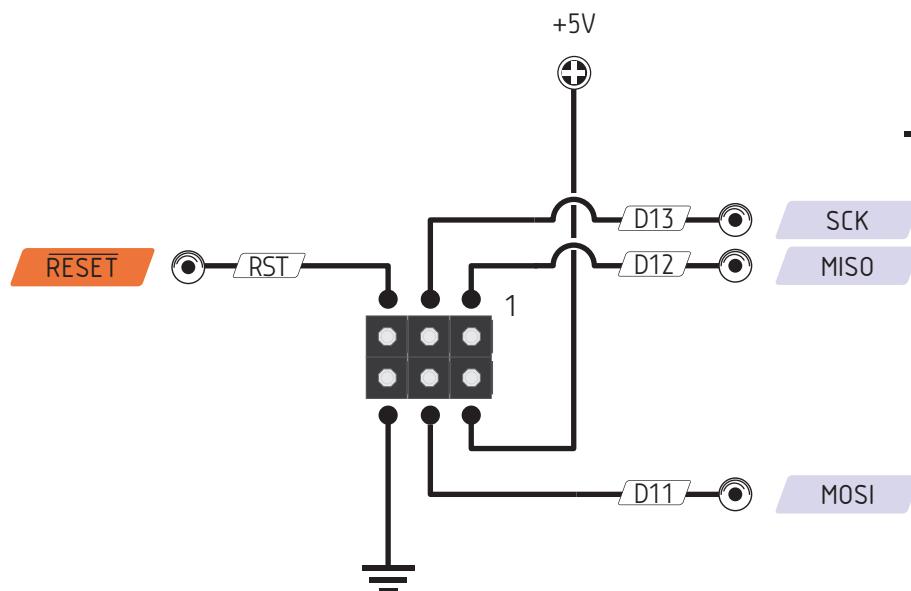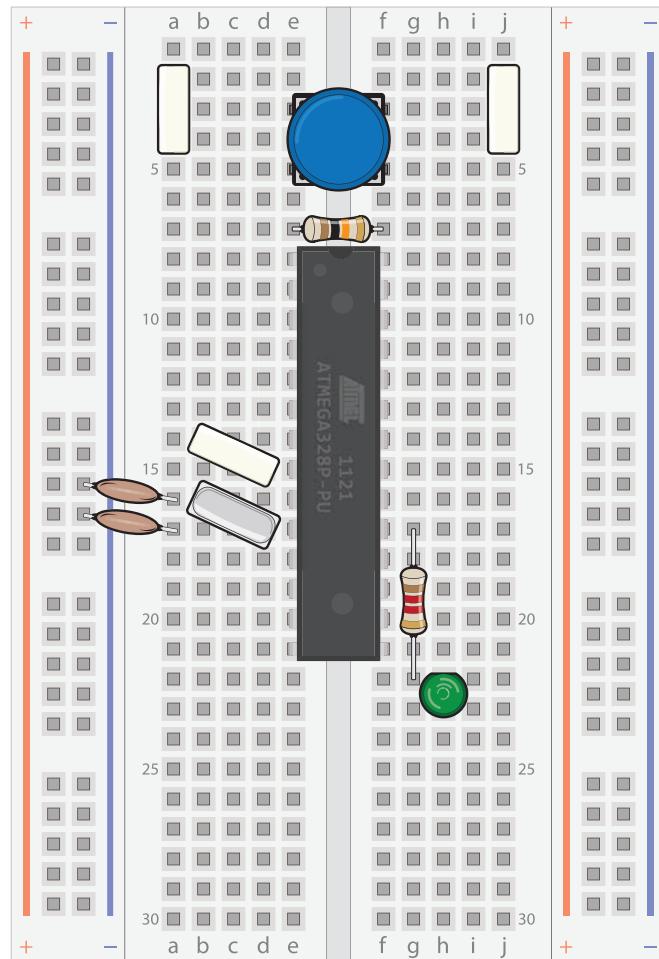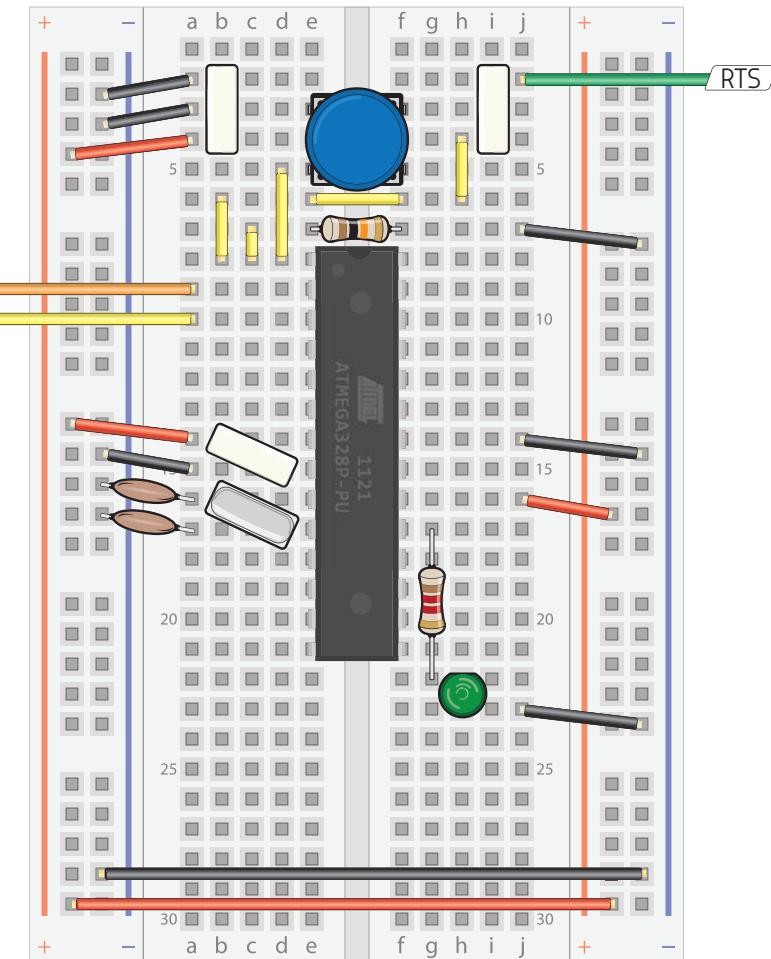+5V

RESET — RST

D13 — SCK
D12 — MISO

1

D11 — MOSI

RTS
TX
RX
VCC
CTS
GND

100nF
104 J100

100nF

10kΩ

+5V

100nF

Reset

RST
D0 RX
D1 TX
D2
D3
D4

22pF
16MHz

100nF

ATMEGA328P-PU
1121

AN5
AN4
AN3
AN2
AN1
AN0
AGND
AREF
AVCC
D13
D12
D11
D10
D9

D5
D6
D7
D8

22

220Ω
K
A

A   K

Don't forget to connect all
the ground wires together! ⚠️

B7

0-1.es/B7

DIY Microcontroller Board
Breadboard

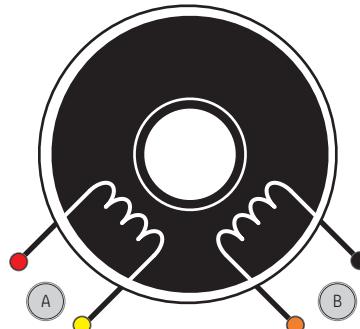*Step 1 of 2*

Step 2 of 2
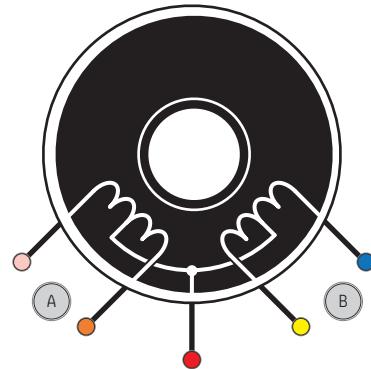
B8

0-1.es/B8

Stepper Motor
Winding Configurations

Not all manufacturers use the color schemes represented here, please check the datasheet

4-Lead Bipolar
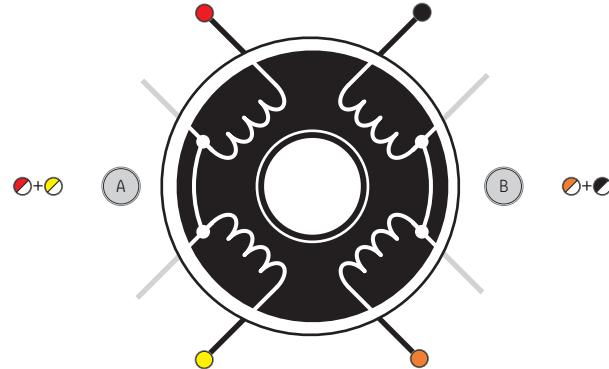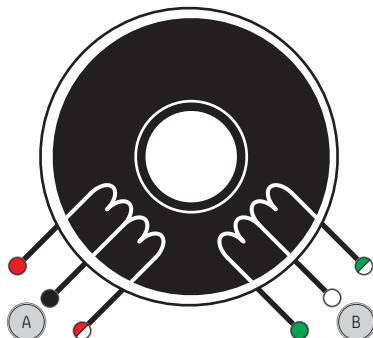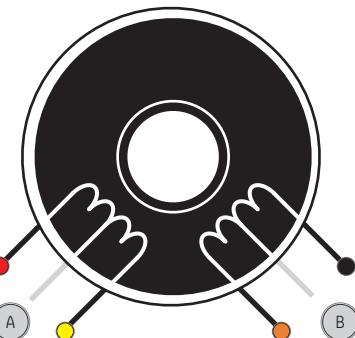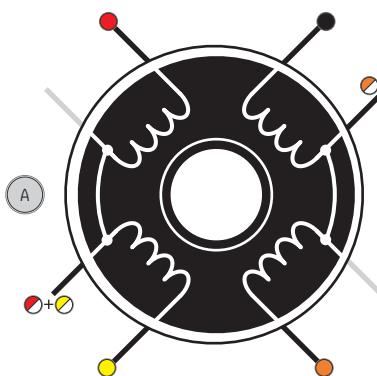
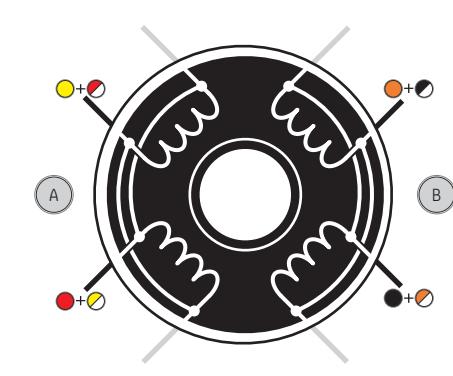

5-Lead Unipolar

8-Lead Bipolar (Series)
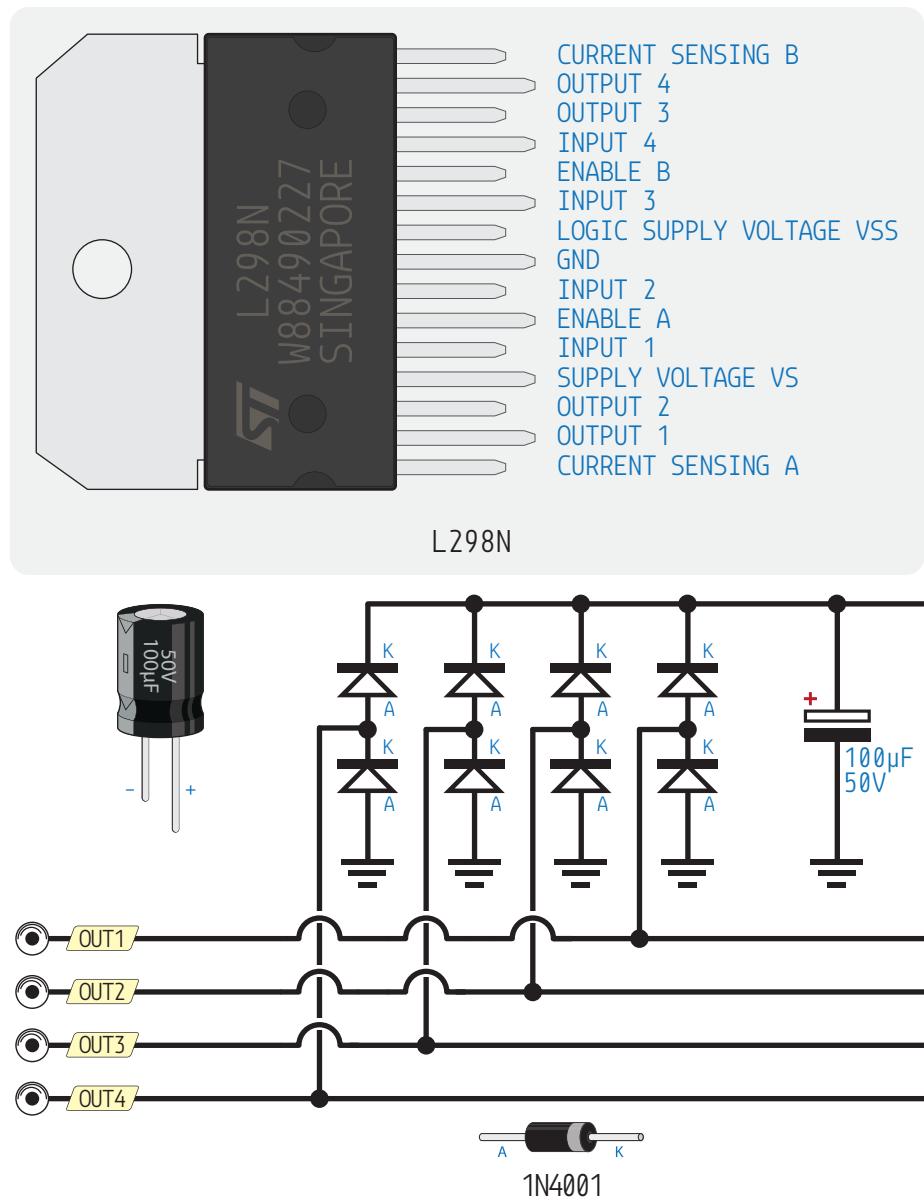

6-Lead Unipolar

6-Lead Bipolar (Series)

8-Lead Unipolar

8-Lead Bipolar (Parallel)

B9

0-1.es/B9

L298N Motor Driver
Basic Connections

CURRENT SENSING B
OUTPUT 4
OUTPUT 3
INPUT 4
ENABLE B
INPUT 3
LOGIC SUPPLY VOLTAGE VSS
GND
INPUT 2
ENABLE A
INPUT 1
SUPPLY VOLTAGE VS
OUTPUT 2
OUTPUT 1
CURRENT SENSING A

L298N

L298N
W88490227
SINGAPORE

⚠ +5...+46V

+5V

100nF

100nF

1W ⛔

0.47Ω

0.47Ω

104 J100

50V
100µF

+
100µF
50V

K K K K
A A A A
K K K K
A A A A

1N4001
A   K

1 IN1   IN3 4
2 IN2   IN4 5
3 ENAA   ENAB 6

CH1
OUT1
OUT2

CH2
OUT3
OUT4

Don't forget to connect all
the ground wires together! ⚠