Today's Plan

- Announcements: midterm, projects
- Review activity 4
- Ultrasonic mini-project
- Sensors
- Serial interfaces
- Analog output
- Driving external loads
- Motors: dc motors, stepper motors, servos

Announcements:

- Midterm coming on **Feb 9**, will be similar to in-class activities we've been having, but **individual**, and longer. Will need to write simple programs in C and/or assembler for MSP430, you will need to extract information from data sheets (which I will provide – example from 2015 posted on course web site), and will need to analyze/explain code samples.

Announcements:

- **Projects:** Project proposal due this week (Jan 31 – Feb 6).

Activity 4

Complete the C program below so that it will:
1) configure pin P1.0 as an output and P1.3 as an input.
2) then enter a loop that continuously reads the
P1.3 value. Each time the program sees a
change from Low to High, it should toggle the P1.0 output.

```
#include <msp430.h>
int main(void){

   WDTCTL = WDTPW + WDTHOLD;


   while(1){




   }
}
```

Activity 4

Complete the C program below so that it will:

1) configure pin P1.0 as an output and P1.3 as an input.

2) then enter a loop that continuously reads the P1.3 value. Each time the program sees a change from Low to High, it should toggle the P1.0 output.

```
#include <msp430.h>
int main(void){
    unsigned char oldval,newval;
    WDTCTL = WDTPW + WDTHOLD;
    P1DIR = 1; // P1.0 output, all others input
    oldval = P1IN;
    while(1){
        newval = P1IN;
        if (((newval & 8) == 8) && ((oldval & 8) == 0) )
            P1OUT ^= 1;
        oldval = newval;
    }
}
```

Activity 4

Complete the C program below so that it will:
1) configure pin P1.0 as an output and P1.3 as an input.
2) then enter a loop that continuously reads the
P1.3 value. Each time the program sees a
change from Low to High, it should toggle the P1.0 output.

```
#include <msp430.h>
int main(void){

   WDTCTL = WDTPW + WDTHOLD;
   P1DIR = 1; // P1.0 output, all others input

   while(1){
      while (P1IN & 8);
      while (! (P1IN & 8));
      P1OUT ^= 1;

   }
}
```

sits here as long as the pin is high

sits here as long as it is low.

so if we get here, we must have just gone from low to high.

Activity 4

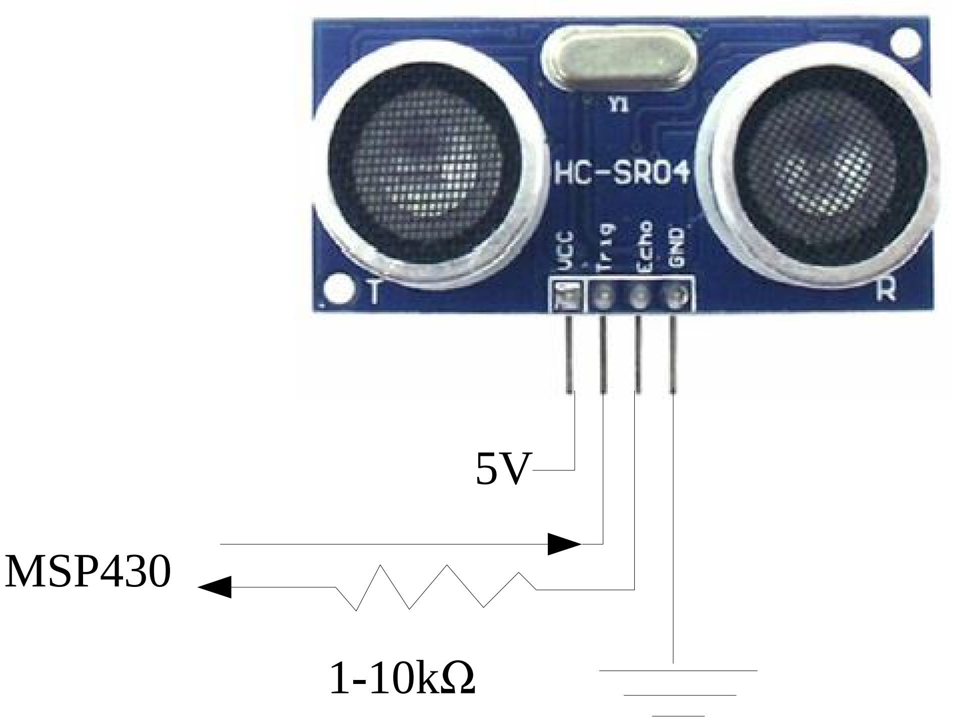
Complete the C program below so that it will:
1) configure pin P1.0 as an output and P1.3 as an input.
2) then enter a loop that continuously reads the
P1.3 value. Each time the program sees a
change from Low to High, it should toggle the P1.0 output.

```
#include <msp430.h>
int main(void){

   WDTCTL = WDTPW + WDTHOLD;
   P1DIR = 1; // P1.0 output, all others input

   while(1){
      while (P1IN & 8);
      while (! (P1IN & 8));
      P1OUT ^= 1;

   }
}
```

Something like this might be useful for
the distance sensor measurement?

Also:
__delay_cycles(10);

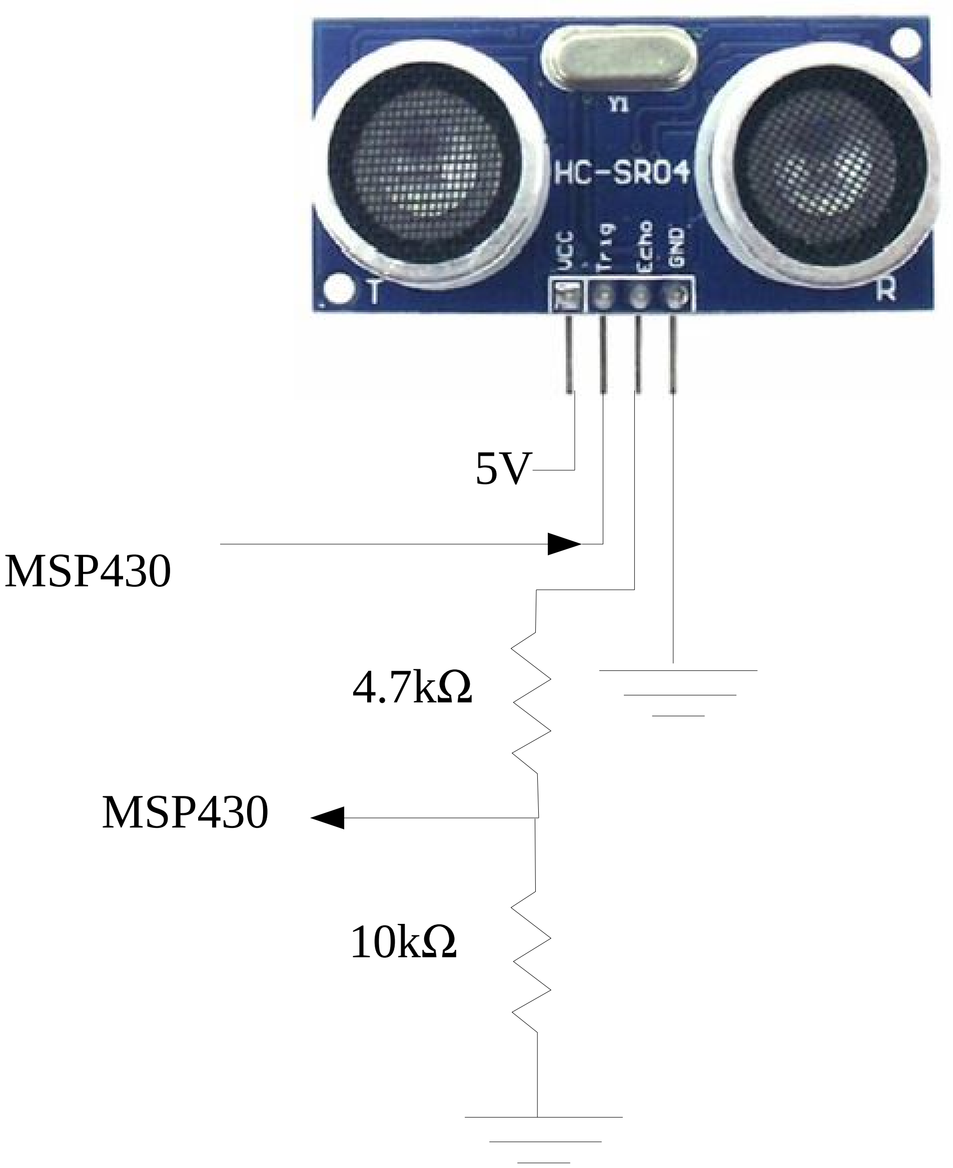
Connecting the ultrasonic distance sensor:



The SR04 is a 5V device! To protect the MSP430 input from it, you should put a resistor in between the 'Echo' line and the MSP430.

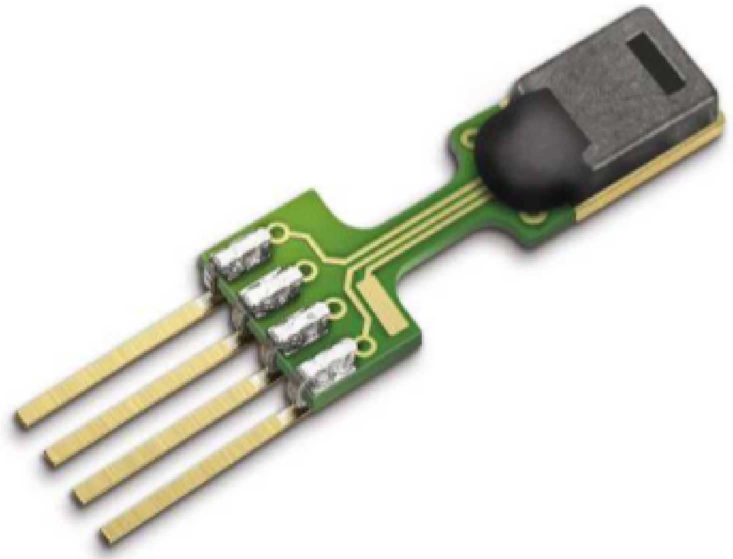
Connecting the ultrasonic distance sensor:

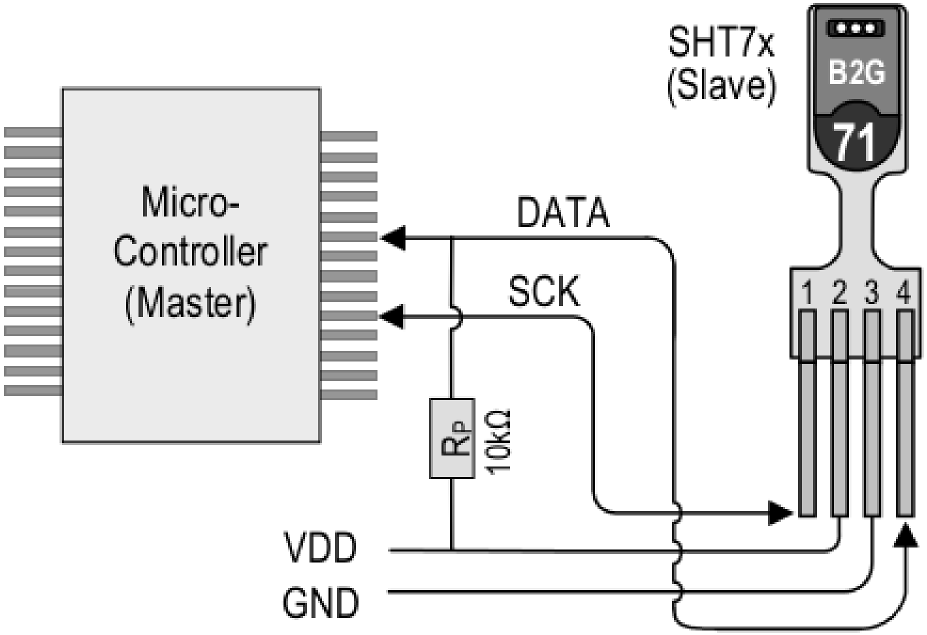
Or, even better:



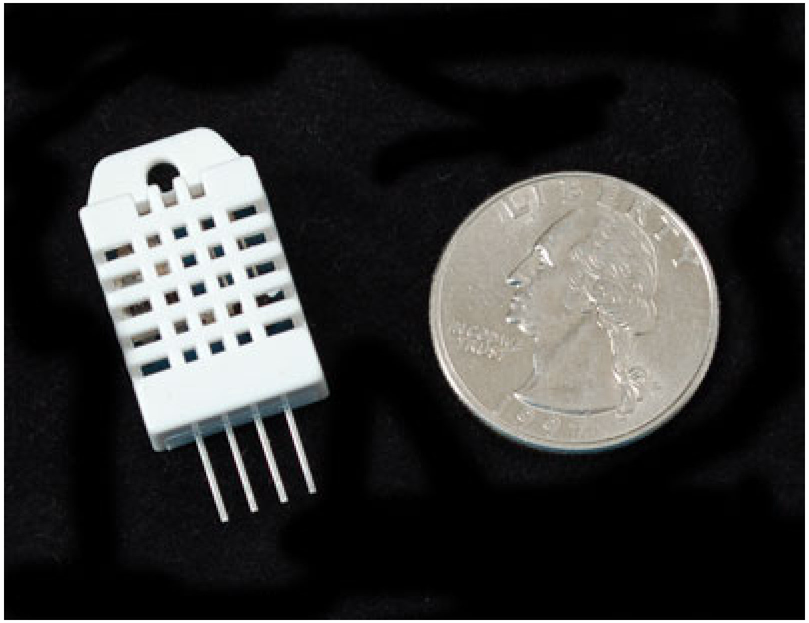
SHT75 Temperature and Humidity Sensor

- Fully Calibrated
- Digital output
- Low power consumption
- Excellent long term stability
- two-wire serial interface.
- Accuracy +/- 0.5C





DHT22 Temperature and humidity sensor



Accuracy	humidity +/-2%RH(Max +-5%RH);	temperature +/-0.2C
Resolution or sensitivity	humidity +/-0.1%RH;	temperature +/-0.1C
Repeatability	humidity +/-1%RH;	temperature +/-0.2C
Humidity hysteresis	+/-0.3%RH	
Long-term Stability	+/-0.5%RH/year	
Sensing period	Average 2s	
Interchangeability	fully interchangeable	

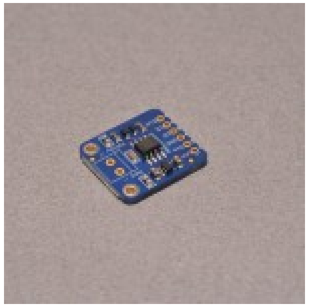
DS18B20 Temperature only

-Inexpensive,

- somewhat complicated interface
- high resolution 0.0625 degrees
- accuracy (+/- 0.5C)
- easy to multiplex many sensors

Also:

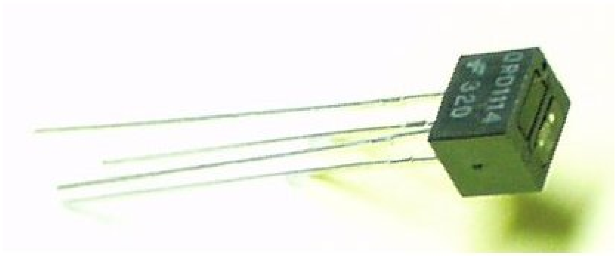
- Thermocouples
- Thermistors
- IR no contact sensor



MLX90614:

Distance Sensors:

- Optical:
  short range QRD1114,
  medium range GP2D12



- Ultrasonic

Magnetic Field Sensors:

- Hall effect
  on-off vs field measurement
- magneto-resistive
- magneto-inductive

eg: Devantech CMPS03 compass module

Position Sensor:

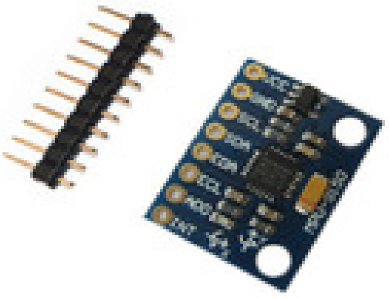
- Potentiometers (3/4 turn, 10 turn)
- Linear potentiometers

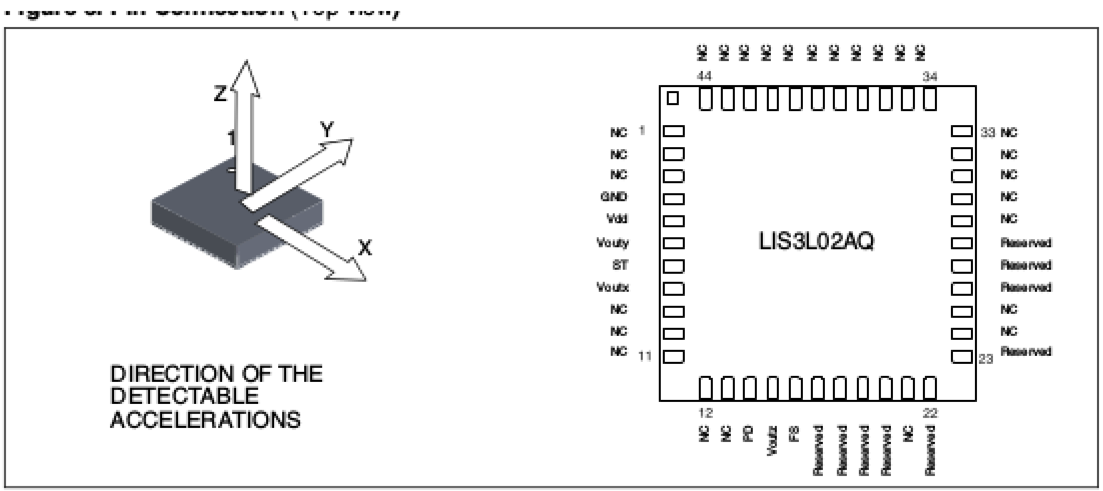
Accelerometers, Gyroscopes:

- 1 axis, 2 axis, 3 axis

EG: MPU9150: 3 axis gyroscope,
3 axis accelerometer+ 3 axis magnetic field
I^2C interface for ~$10.

EG: LIS3L02AQ – 3 axis accelerometer
with analog outputs.





Pressure Sensors

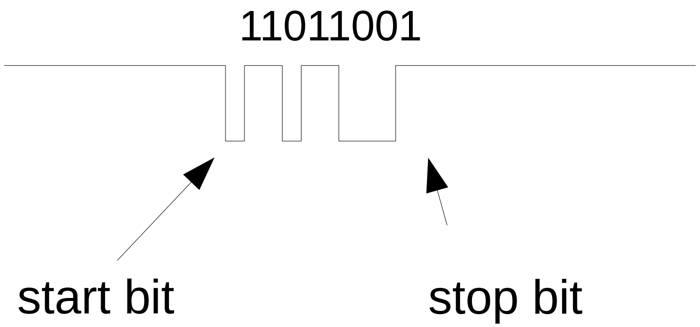
- Gas or liquid (MPX5100)
- Mechanical (IESF-R-5L)
- Force sensitive resistors

Serial interfaces

Many sensors use “standard” interfaces such as I^{2}C (inter-integrated circuit) or SPI (serial peripheral interface) to talk to the microcontroller.

The MSP430 has a module that can ease using these interfaces (Universal Serial Communication Interface, USCI, which can speak: I^{2}C, SPI and UART).

UART: Universal Asynchronous Receiver/Transmitter


11011001

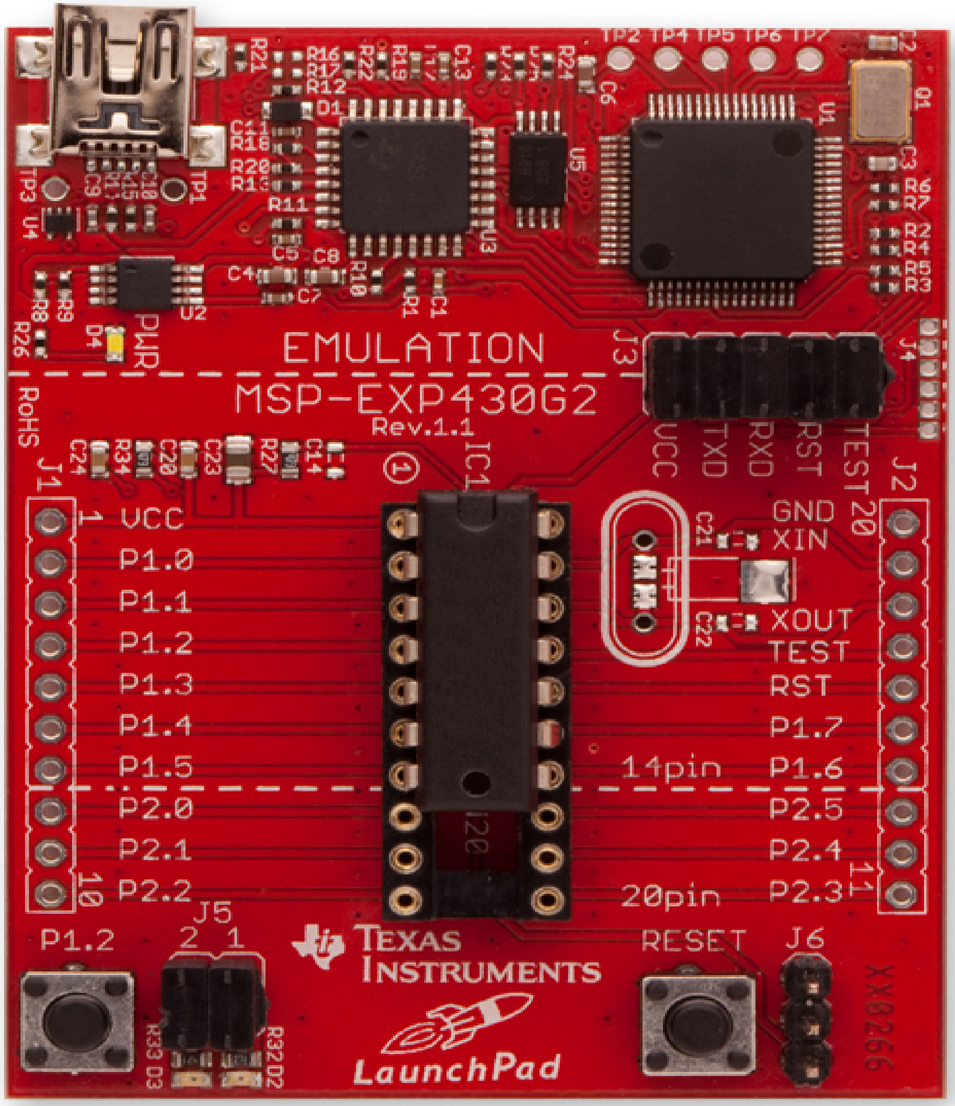
start bit

stop bit

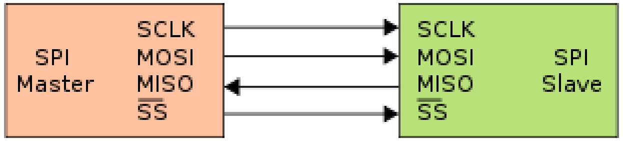
- 3 lines for bi-directional communication: ground, transmit, receive
- start bit is always low, stop bit is always high.
- usually have 8 data bits in between, (but sometimes 5 or 6 or 7)
- least significant bit first, most significant bit last
- sometimes there is parity bit after the data

The USCI can output bytes and decode incoming bytes.

- to transmit a byte, just write it to UCA0TXBUF = byte;
- to receive a byte, set up interrupt to trigger when byte received, then read from receive buffer: byte = UCA0RXBUF;


EMULATION
MSP-EXP430G2
Rev.1.1
PWR
J1
J2
J3
J4
J5
J6
IC1
VCC
TXD
RXD
RST
TEST
1 VCC
P1.0
P1.1
P1.2
P1.3
P1.4
P1.5
P2.0
P2.1
10 P2.2
GND 20
XIN
XOUT
TEST
RST
P1.7
14pin P1.6
P2.5
P2.4
20pin P2.3 11
P1.2
2 1
RESET
TEXAS INSTRUMENTS
LaunchPad
RoHS

SPI: Serial Peripheral Interface

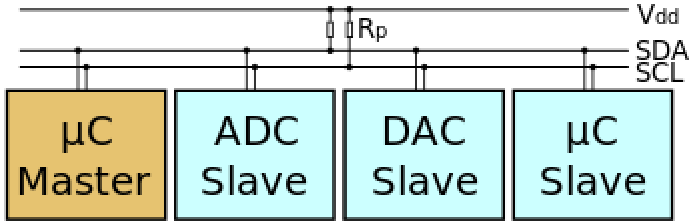


SCLK: clock from master
MOSI: Master out, slave in
MISO: Master in, slave out.
Slave Select

On every toggle of the clock, bits are transmitted in both directions, though not always useful. Communications controlled completely by the master.

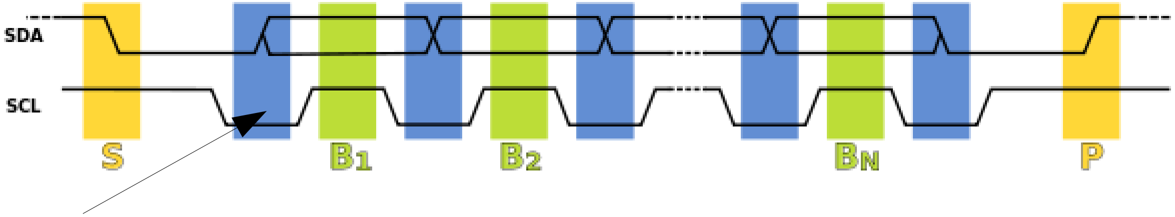
point-to-point, one master, one slave.

I2C: Inter-integrated Circuit



SDA – serial data
SCL – serial clock

Both lines are open-drain, pulled up with pull-up resistors



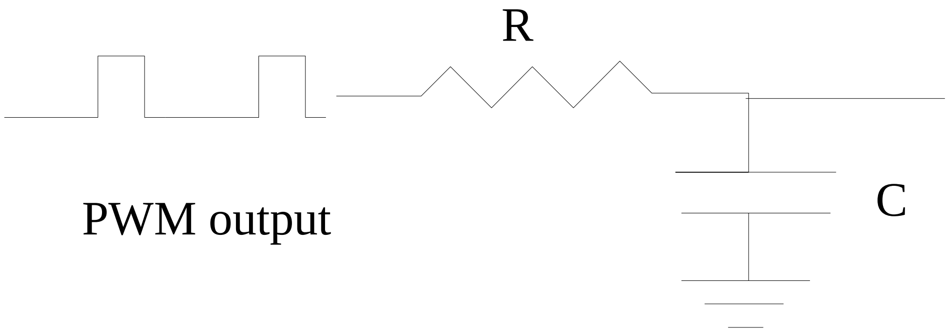
data line changes when clock is held low.

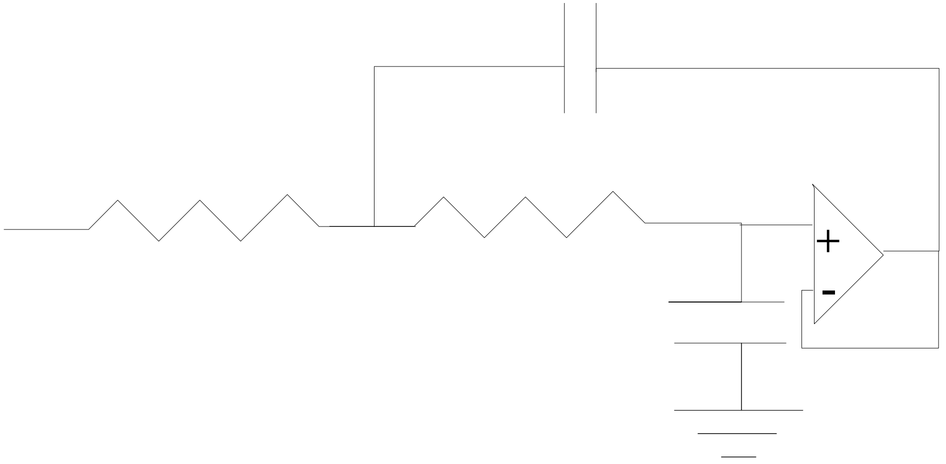
I2C is a bus: can be multiple masters, multiple slaves on the bus.

Analog Output:

The MSP430G2553 doesn't have a DAC. If you want an adjustable analog output, there are a couple of options:

- Add an external DAC (serial or parallel)
- low-pass filter a PWM output.

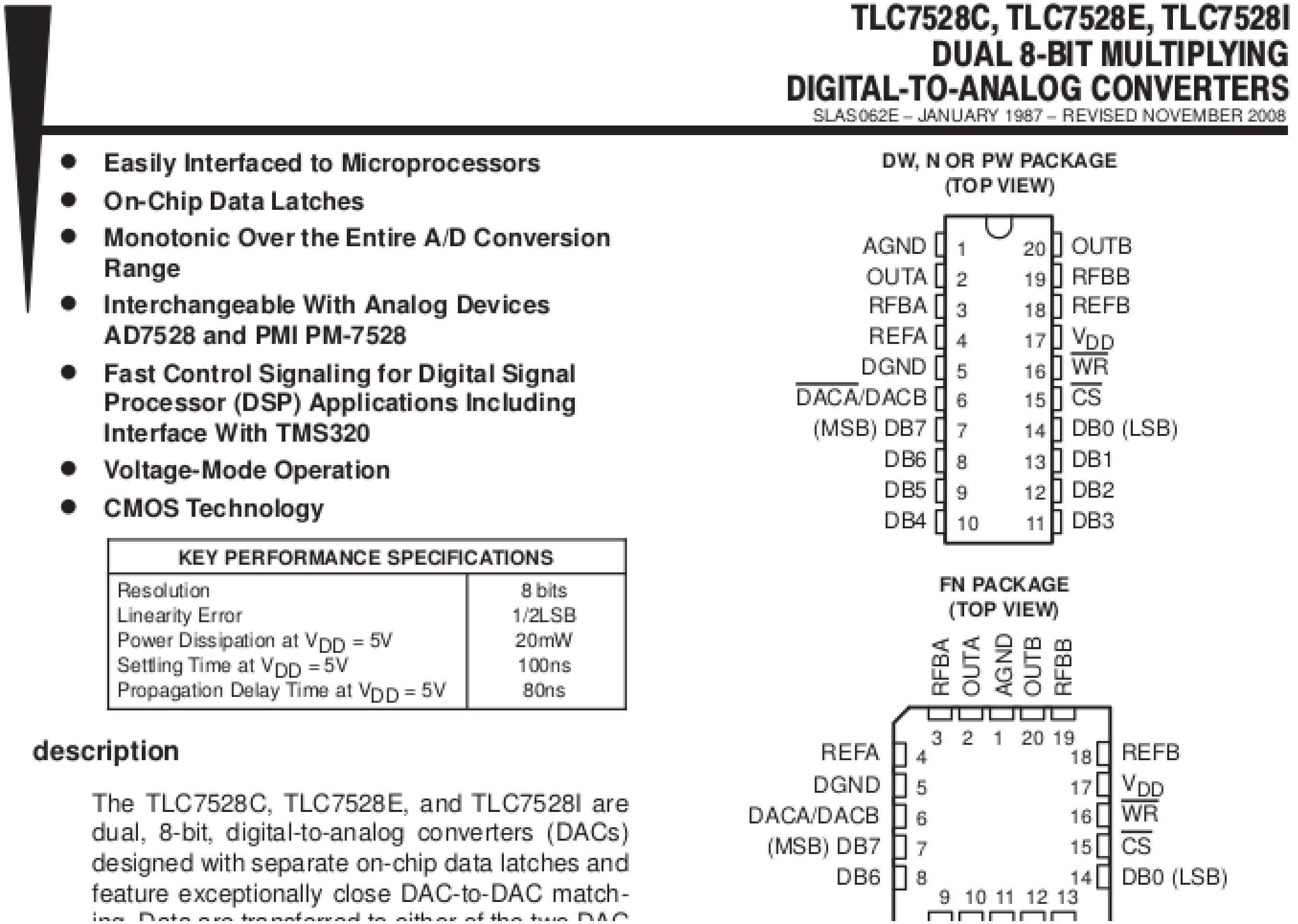




2nd order Low-pass filter

Analog Output:

Parallel DAC: eg TLC7528, Dual 8bit multiplying digital to analog converter.



TLC7528C, TLC7528E, TLC7528I
DUAL 8-BIT MULTIPLYING
DIGITAL-TO-ANALOG CONVERTERS
SLAS062E – JANUARY 1987 – REVISED NOVEMBER 2008

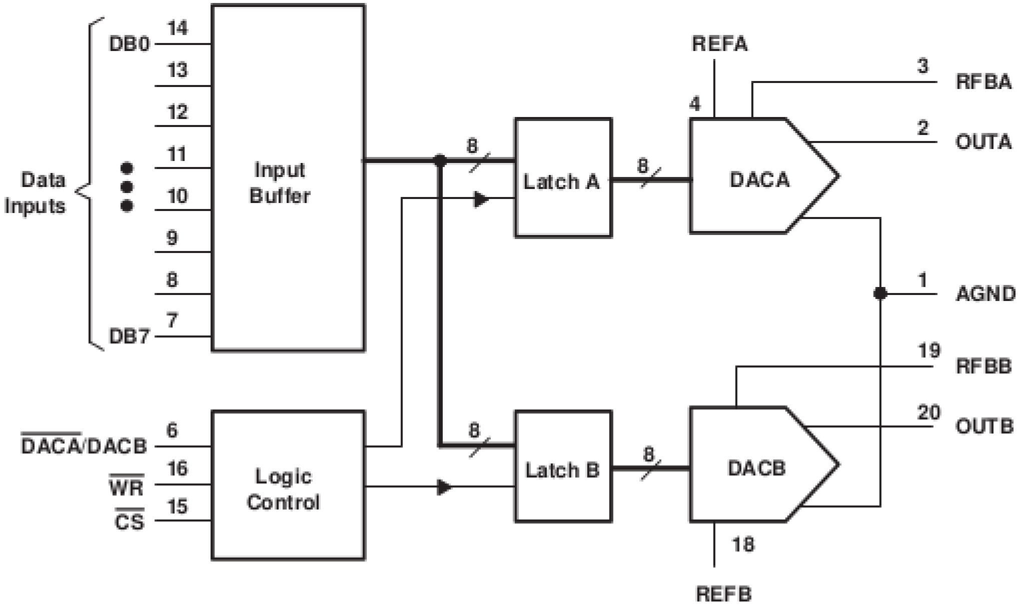
- **Easily Interfaced to Microprocessors**
- **On-Chip Data Latches**
- **Monotonic Over the Entire A/D Conversion Range**
- **Interchangeable With Analog Devices AD7528 and PMI PM-7528**
- **Fast Control Signaling for Digital Signal Processor (DSP) Applications Including Interface With TMS320**
- **Voltage-Mode Operation**
- **CMOS Technology**

KEY PERFORMANCE SPECIFICATIONS	
Resolution	8 bits
Linearity Error	1/2LSB
Power Dissipation at V_{DD} = 5V	20mW
Settling Time at V_{DD} = 5V	100ns
Propagation Delay Time at V_{DD} = 5V	80ns

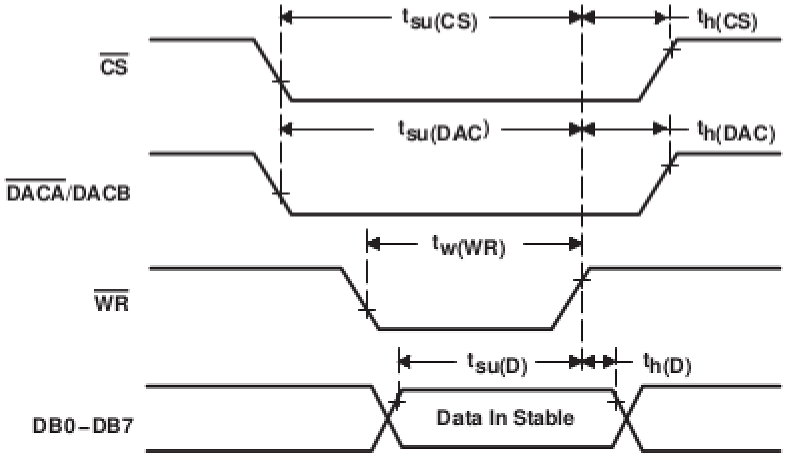
description

The TLC7528C, TLC7528E, and TLC7528I are dual, 8-bit, digital-to-analog converters (DACs) designed with separate on-chip data latches and feature exceptionally close DAC-to-DAC matching. Data are transferred to either of the two DAC

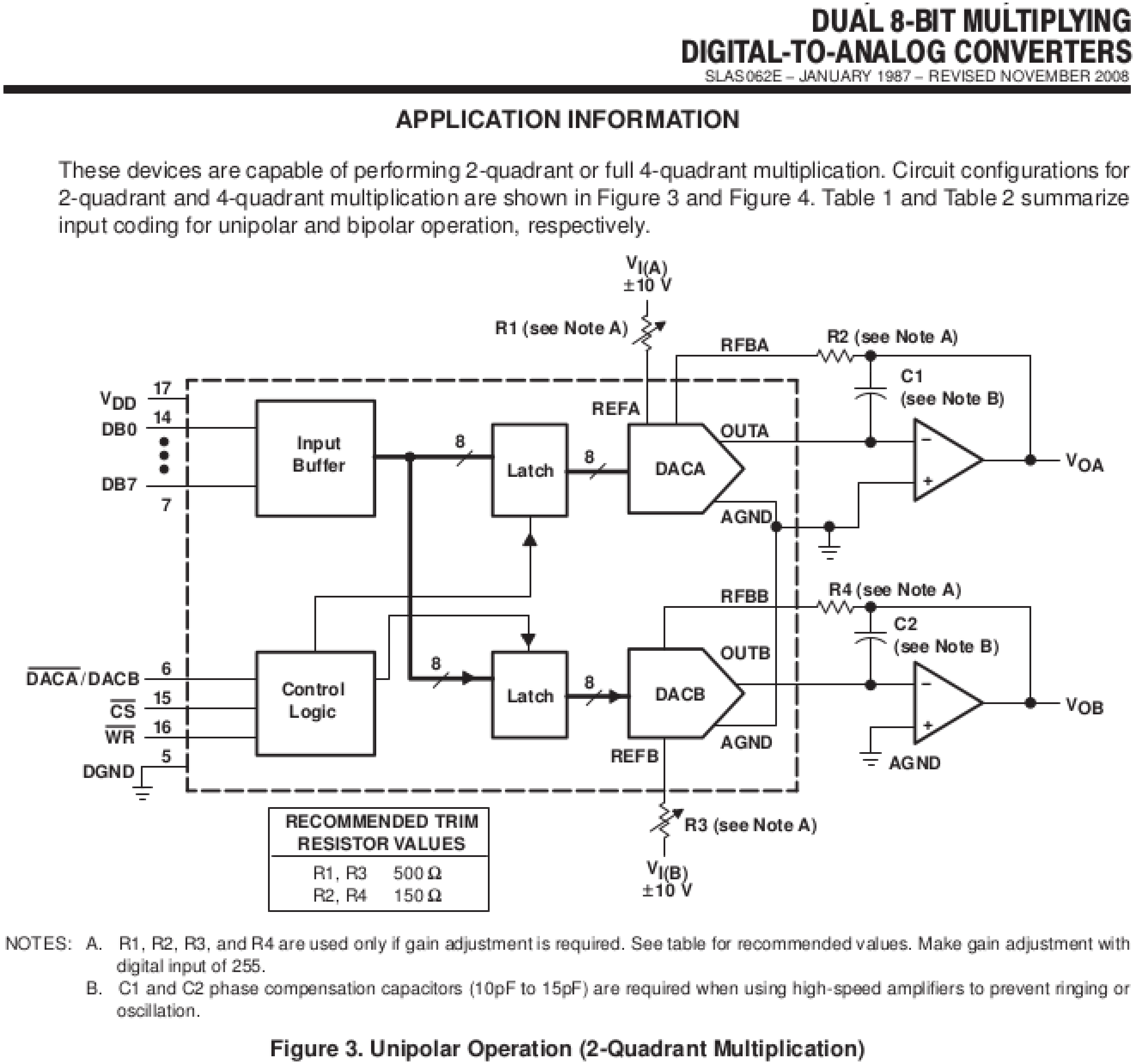
DAC: TLC7528



operating sequence



TLC7528 is a current DAC:



DUAL 8-BIT MULTIPLYING DIGITAL-TO-ANALOG CONVERTERS

SLAS062E – JANUARY 1987 – REVISED NOVEMBER 2008

APPLICATION INFORMATION

These devices are capable of performing 2-quadrant or full 4-quadrant multiplication. Circuit configurations for 2-quadrant and 4-quadrant multiplication are shown in Figure 3 and Figure 4. Table 1 and Table 2 summarize input coding for unipolar and bipolar operation, respectively.

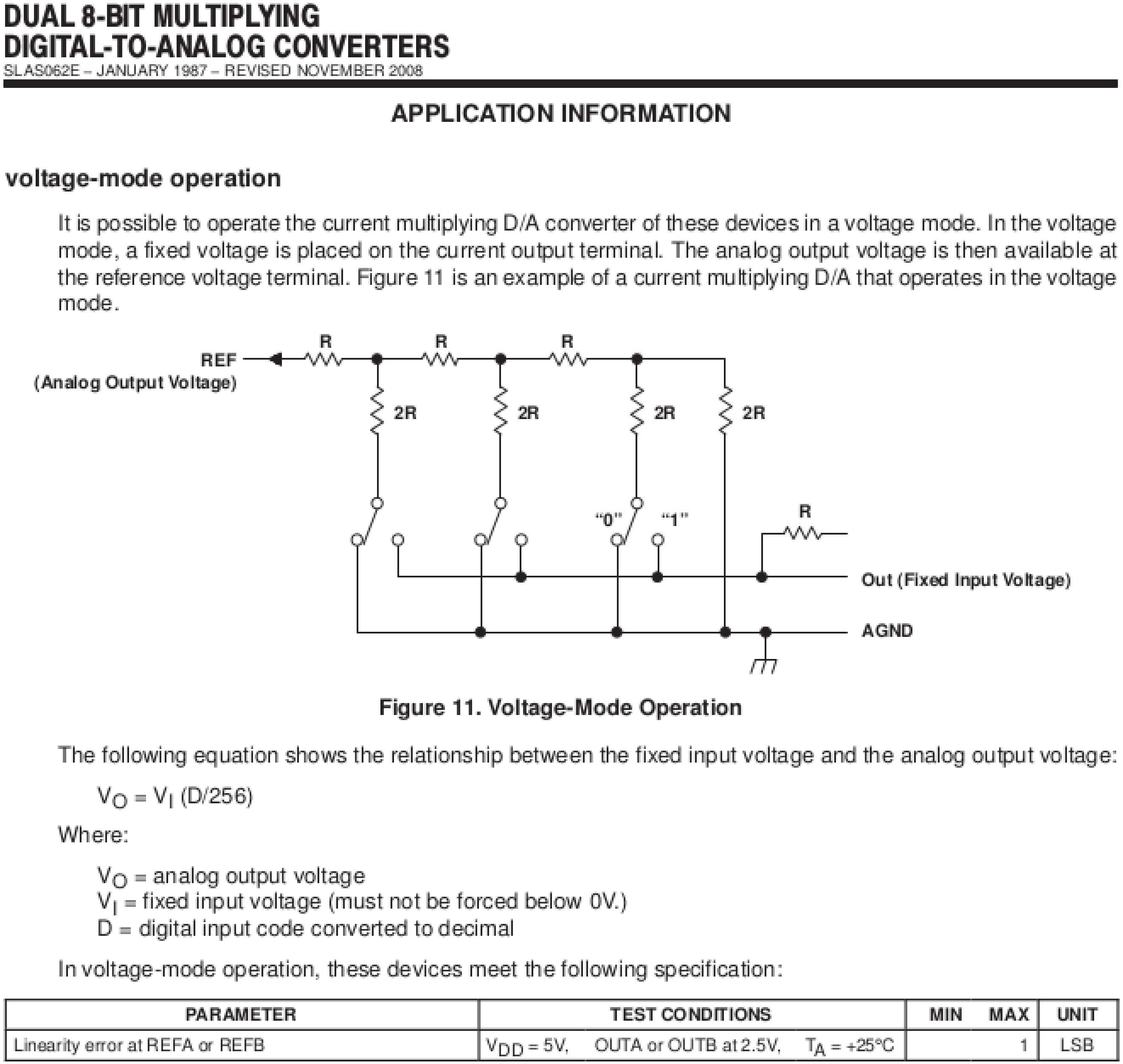
RECOMMENDED TRIM RESISTOR VALUES	
R1, R3	500 Ω
R2, R4	150 Ω

NOTES: A. R1, R2, R3, and R4 are used only if gain adjustment is required. See table for recommended values. Make gain adjustment with digital input of 255.

B. C1 and C2 phase compensation capacitors (10pF to 15pF) are required when using high-speed amplifiers to prevent ringing or oscillation.

Figure 3. Unipolar Operation (2-Quadrant Multiplication)

- But it can be used in a voltage-output mode.



DUAL 8-BIT MULTIPLYING DIGITAL-TO-ANALOG CONVERTERS

SLAS062E – JANUARY 1987 – REVISED NOVEMBER 2008

APPLICATION INFORMATION

voltage-mode operation

It is possible to operate the current multiplying D/A converter of these devices in a voltage mode. In the voltage mode, a fixed voltage is placed on the current output terminal. The analog output voltage is then available at the reference voltage terminal. Figure 11 is an example of a current multiplying D/A that operates in the voltage mode.

Figure 11. Voltage-Mode Operation

The following equation shows the relationship between the fixed input voltage and the analog output voltage:

$$V_O = V_I\,(D/256)$$

Where:

V_O = analog output voltage
V_I = fixed input voltage (must not be forced below 0V.)
D = digital input code converted to decimal

In voltage-mode operation, these devices meet the following specification:

PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
Linearity error at REFA or REFB	V_{DD} = 5V, OUTA or OUTB at 2.5V, T_A = +25°C		1	LSB

Controlling things with the microcontroller

MSP430 P1.x maximum output current: +/- 6 mA (x 3.3V = 20mW)

To drive external loads that are more demanding than logic chips, the MSP430 needs some help.

Some possibilities:

- Beefier logic (eg for LEDs)
- op-amps
- Buffer/driver
- Transistor (bipolar or MOSFET)
- opto-isolators
- Relay
- Solid-state relay
- H Bridge chip (eg for bi-directional motors)

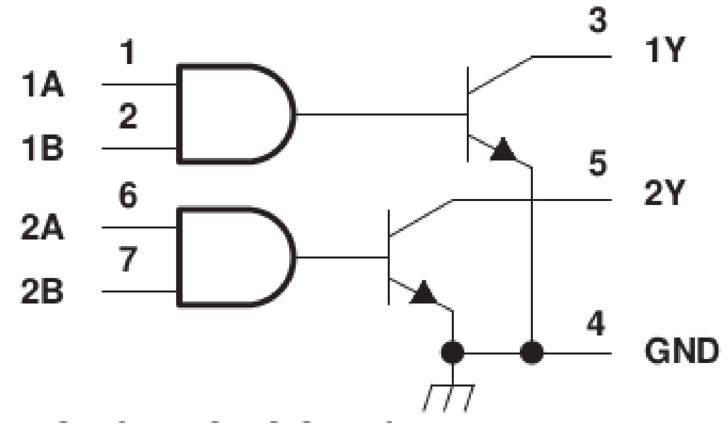
REFERENCE: The Art of Electronics (Horowitz and Hill)

Controlling things with the microcontroller

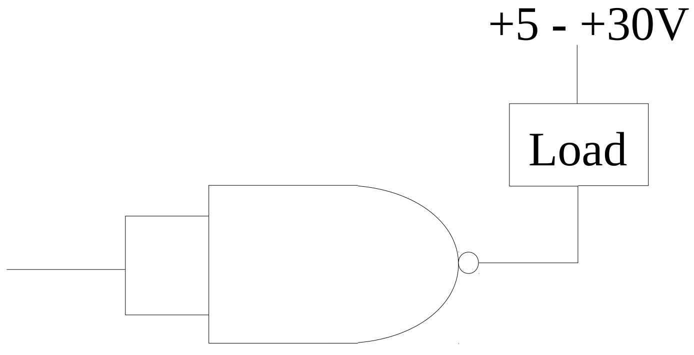
Driver eg SN75451

up to 300 mA

logic diagram (positive logic)



usage:



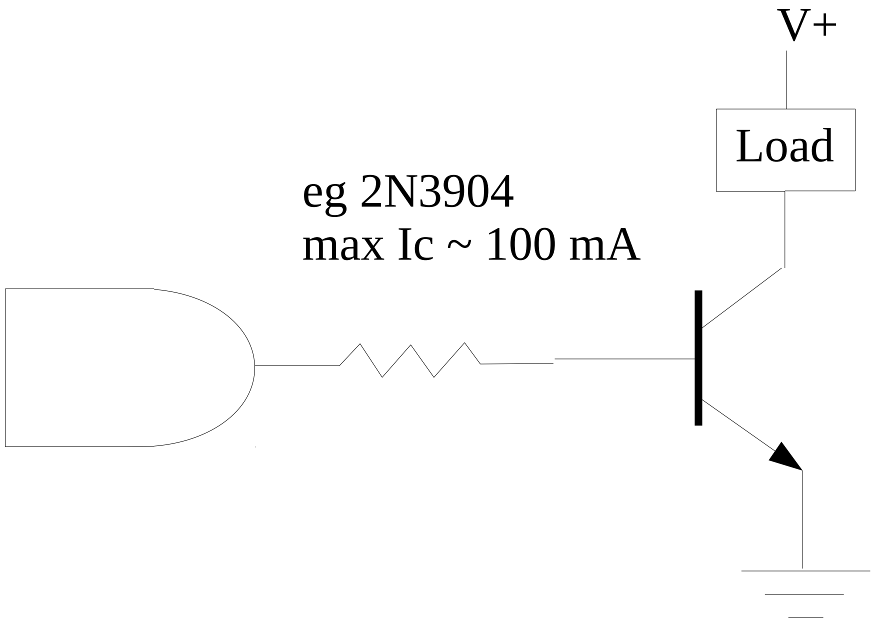
+5 - +30V

Load

logic

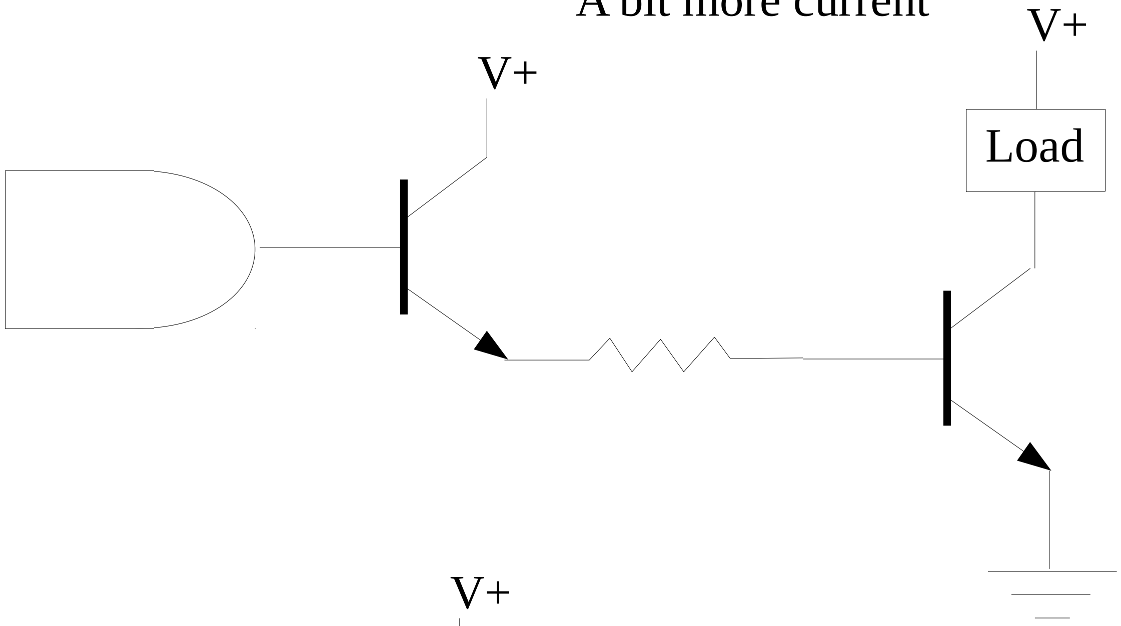
1/2 75451

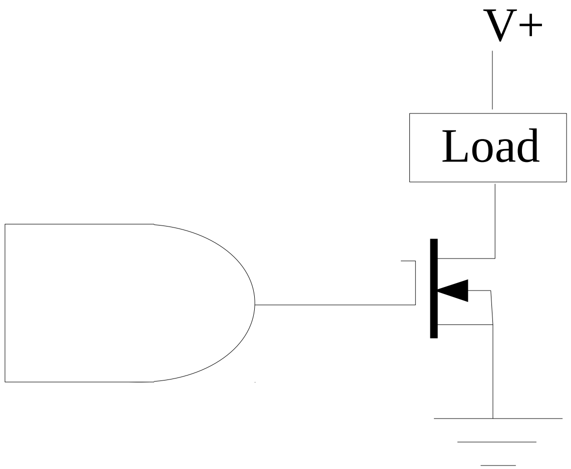
Driving loads: Transistors



eg 2N3904
max Ic ~ 100 mA

A bit more current

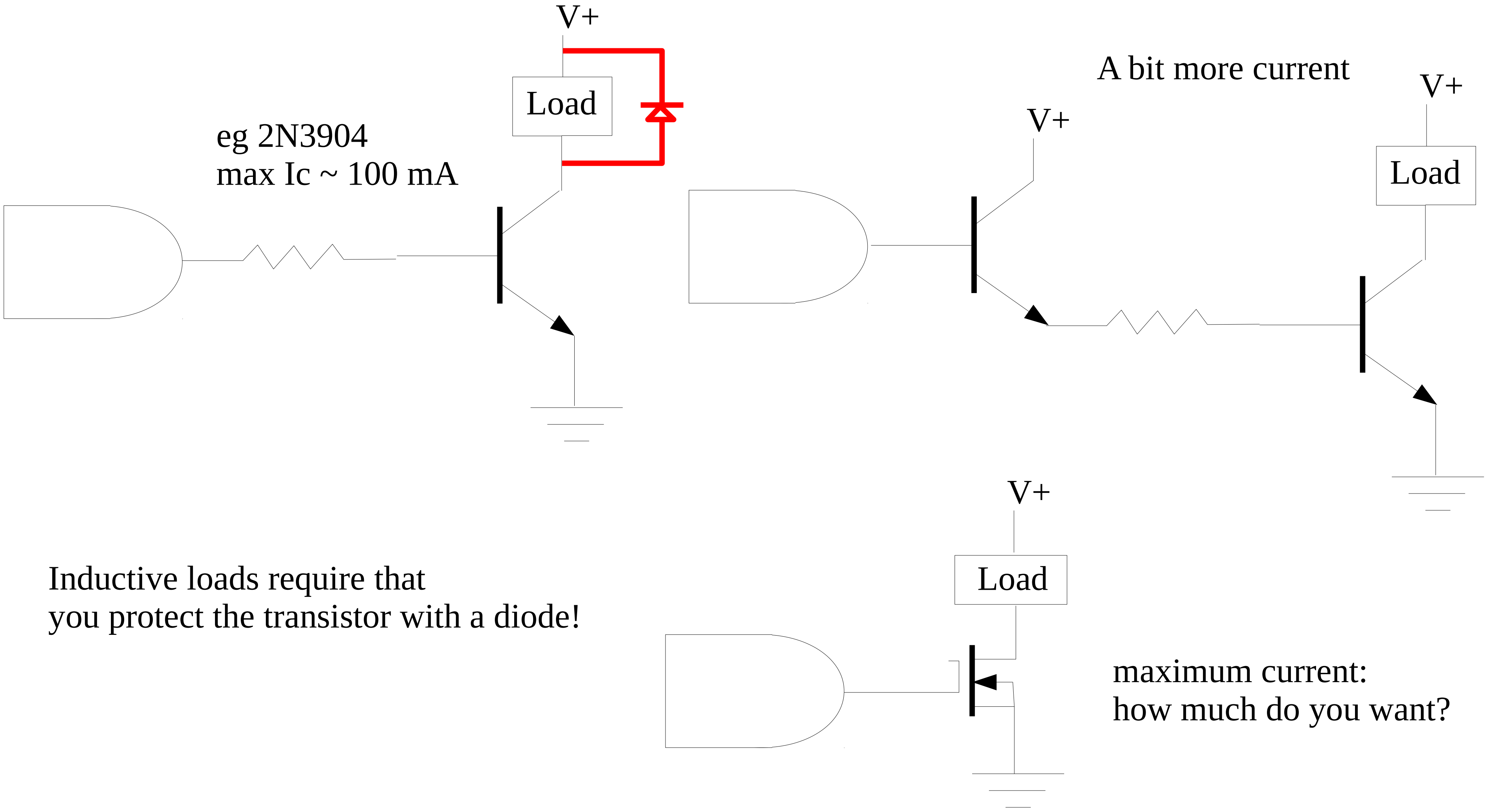




maximum current:
how much do you want?

N-channel mosfet

Driving loads: Transistors



eg 2N3904
max Ic ~ 100 mA

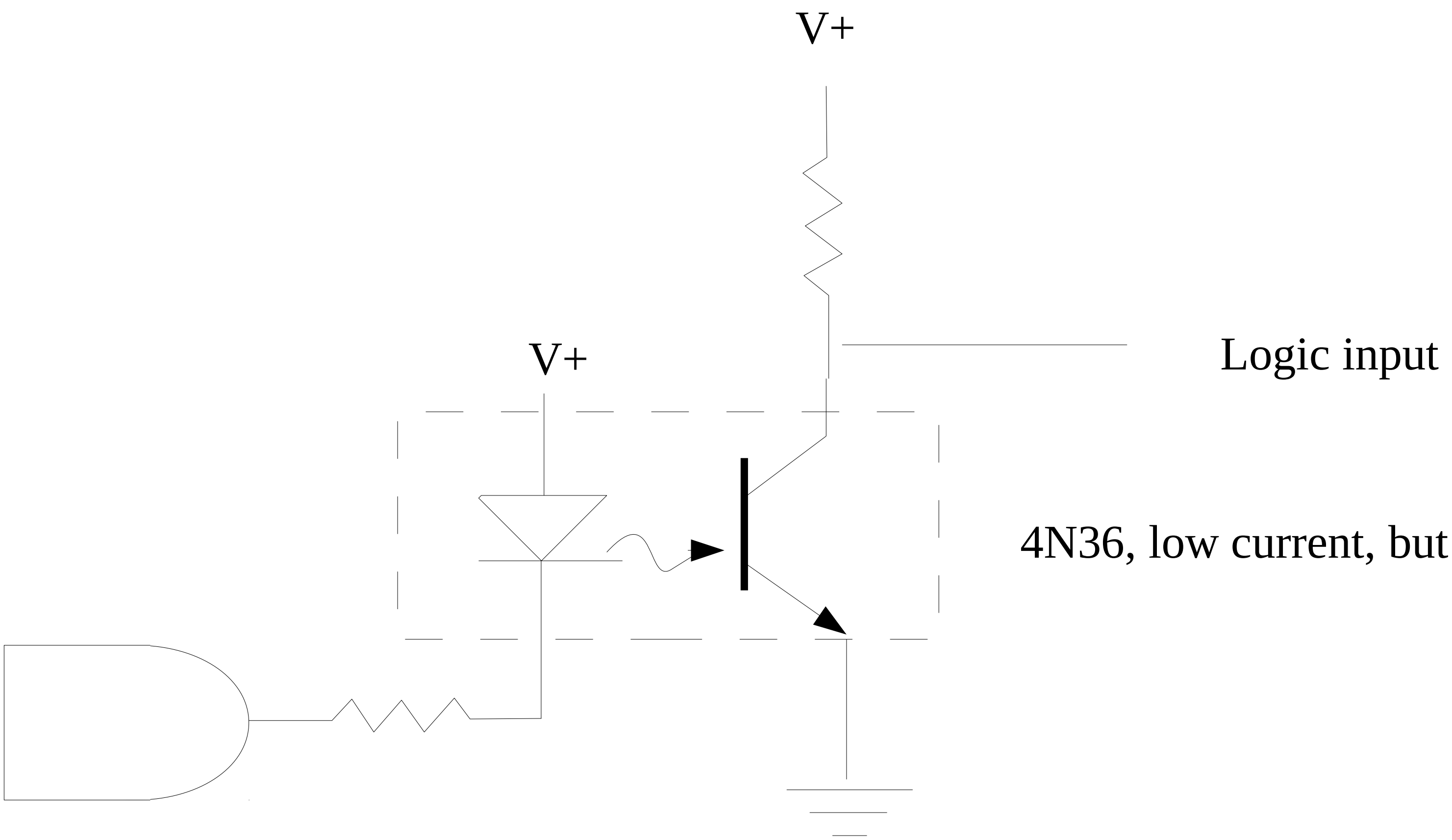
A bit more current

Inductive loads require that
you protect the transistor with a diode!

maximum current:
how much do you want?

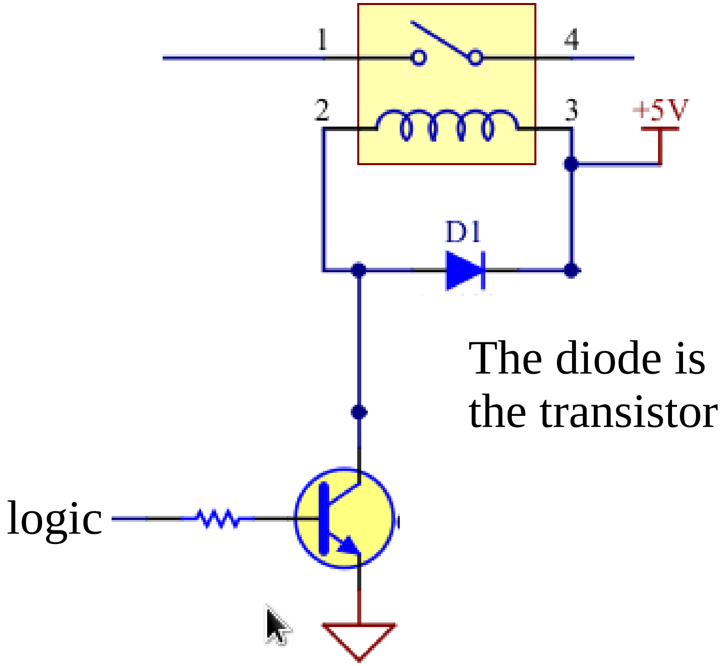
N-channel mosfet

Driving loads: Optoisolators



4N36, low current, but good isolation

Driving loads: Relays



The diode is essential to prevent destroying the transistor on turn-off!

There are some small low-current relays that can be driven directly by logic chips, again, a diode is essential to protect the logic circuit from the inductive spike on turn-off!

Driving loads: Solid-state Relays

good for AC, large loads, fast, repeated switching
(expensive, may need a heat sink), Often will synchronize to line voltage.

eg Crydom D2425: 280VAC, 25A !
$44

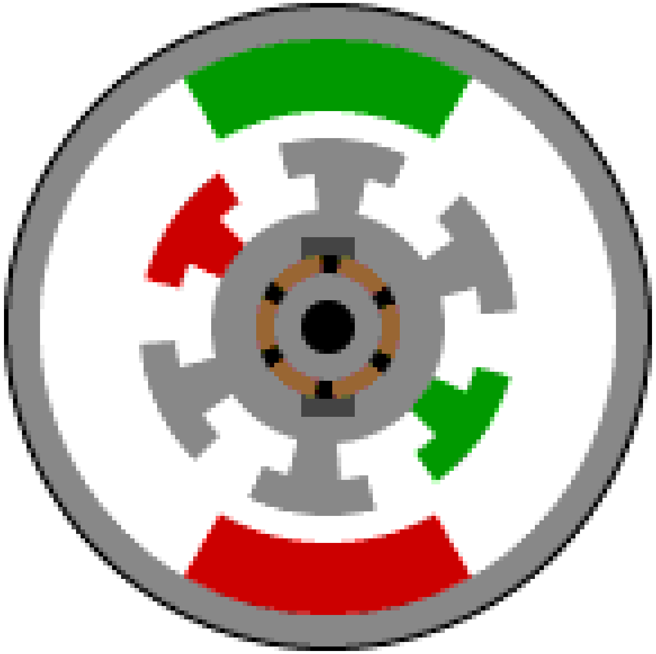
Driving loads: Solid-state Relays

good for AC, large loads, fast, repeated switching
(expensive, may need a heat sink), Often will synchronize to line voltage.

eg Crydom D2425: 280VAC, 25A !
$44

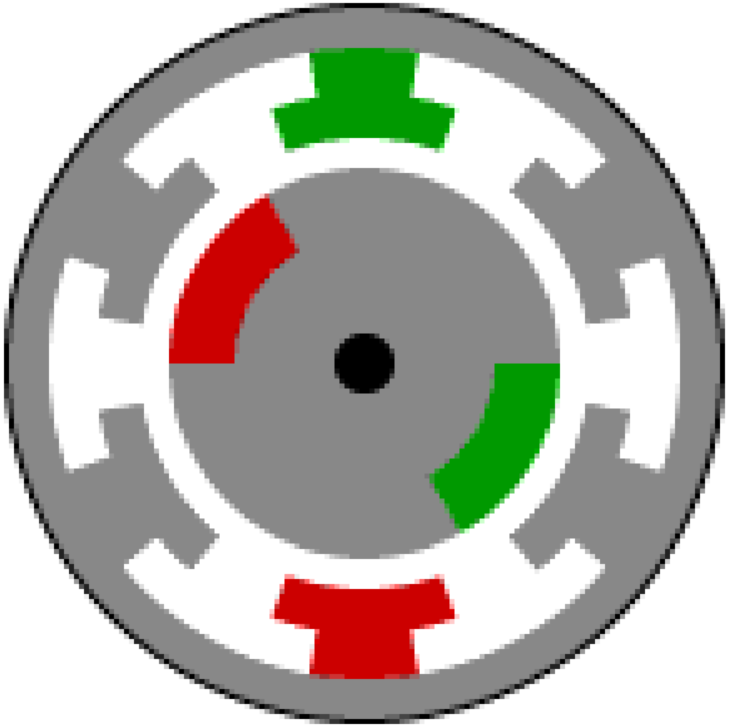
Be careful buying solid-state relays on the grey (Ebay etc) market, there are many 'fakes' out there.

Motors: DC motors



http://www.freescale.com/webapp/sps/site/overview.jsp?code=WBT_MOTORDCTUT_WP

Motors: Brushless DC motors



http://www.freescale.com/webapp/sps/site/overview.jsp?code=WBT_MOTORBLDCTUT_WP

Motors: Servos

- precise position control
- provide a PWM signal to specify position
- typical range of 0-180 degrees

- contains a DC motor, gearing, a potentiometer, control electronics.
- The average PWM voltage is compared to the position, as measured by the potentiometer. The control electronics then drive the motor forward or backward to set the angle as requested.
- Typical PWM period of 20 ms with on time of ~1 – ~2 ms (1.5 ms is 'center'). Wire colours often: red = +5 V, black = ground, white = PWM control.
- Position depends on length of on-pulse, not on duty cycle.

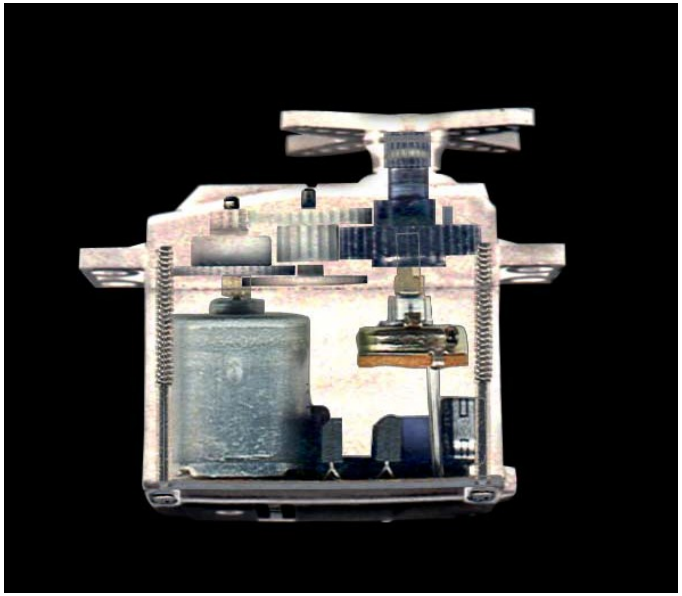
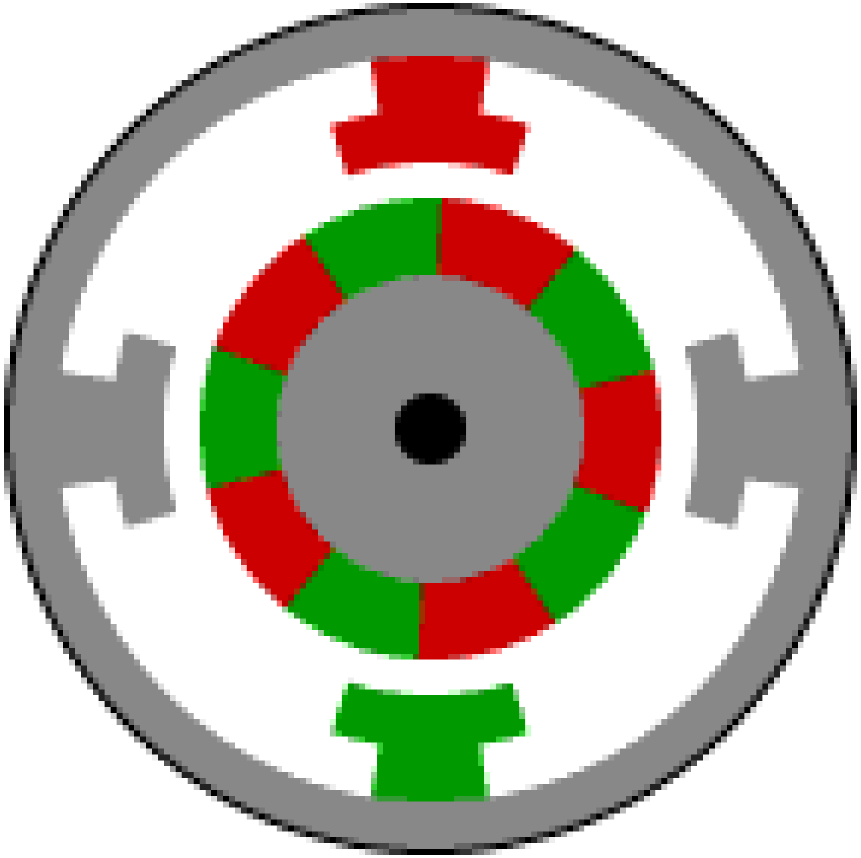


photo from Hobby Servo Fundamentals by Darren Sawicz

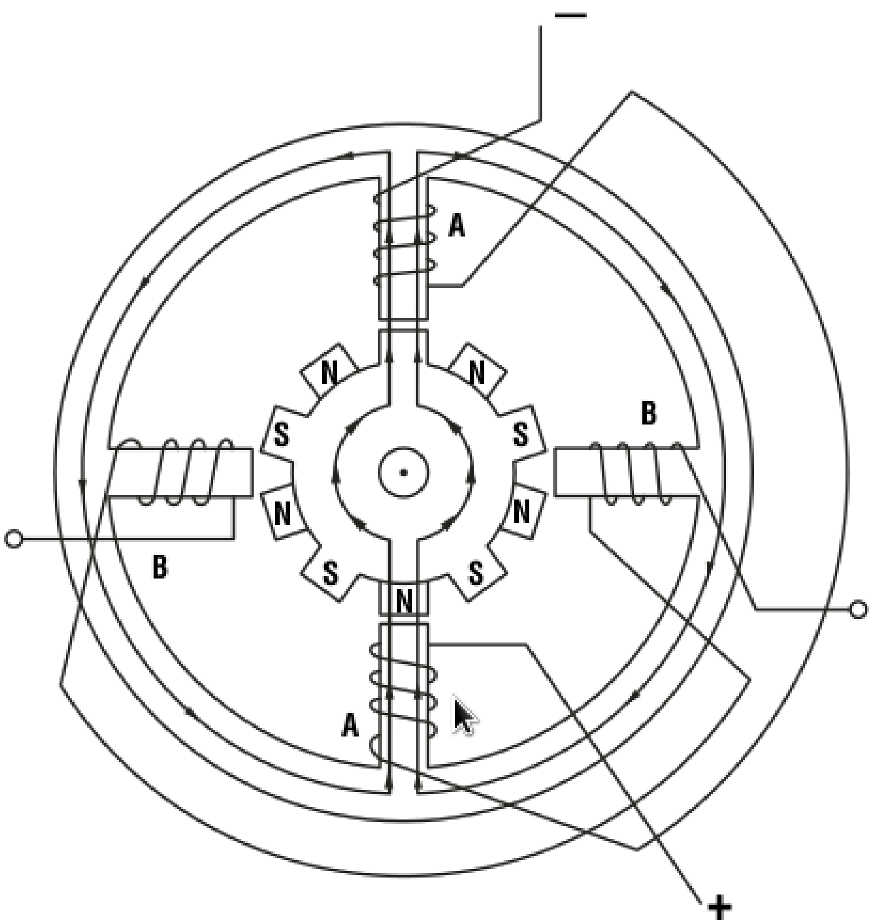
Motors: Stepper motors



Fixed step size, often 200 steps per revolution.

http://www.freescale.com/webapp/sps/site/overview.jsp?code=WBT_MOTORSTEPTUT_WP

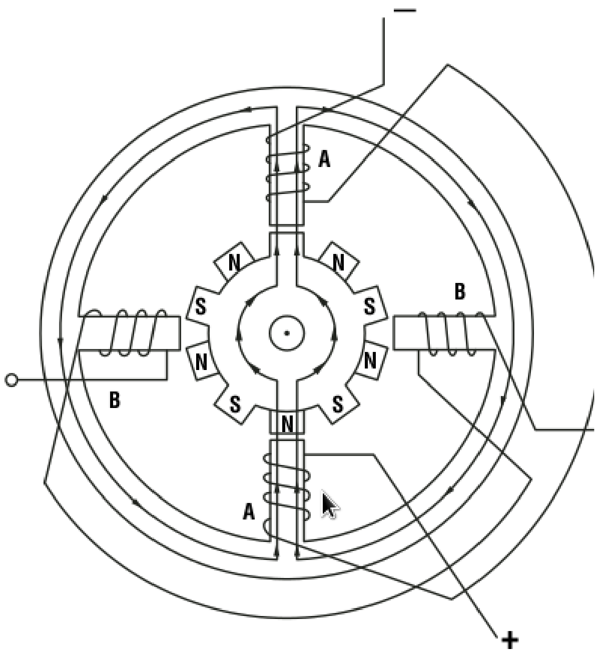
Motors: Stepper motors

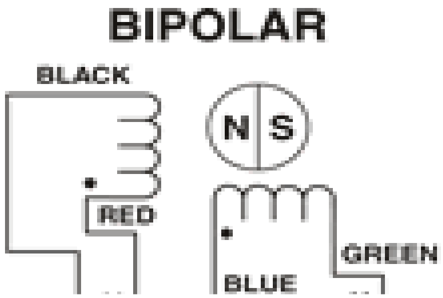


From: Introduction to Step Motors, Applied Motion Products. http://www.omega.ca/auto/pdf/REF_IntroStepMotors.pdf

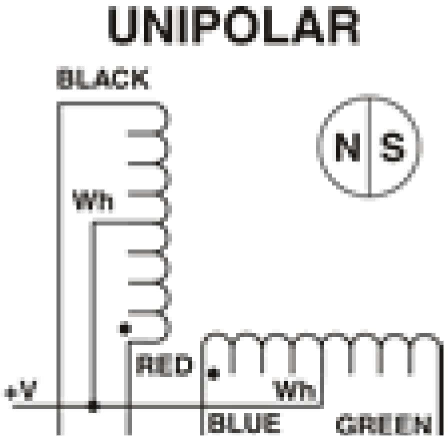
Motors: Stepper motors

Unipolar vs bipolar windings:





4 wires (usually)

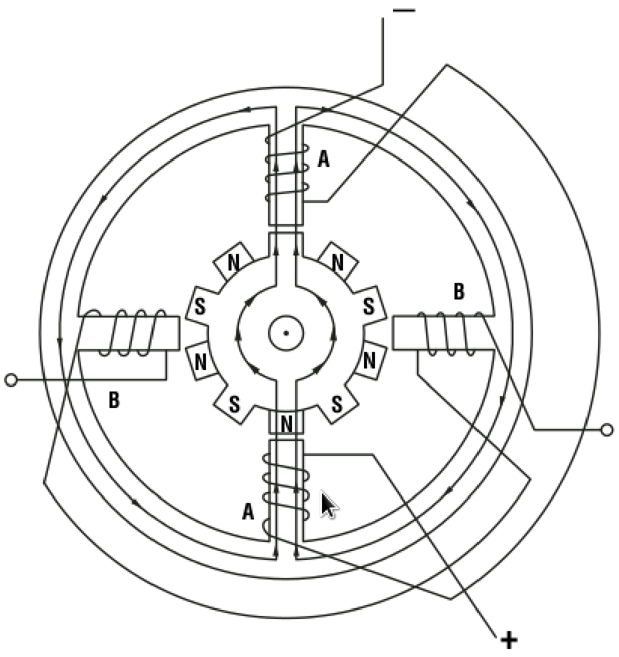


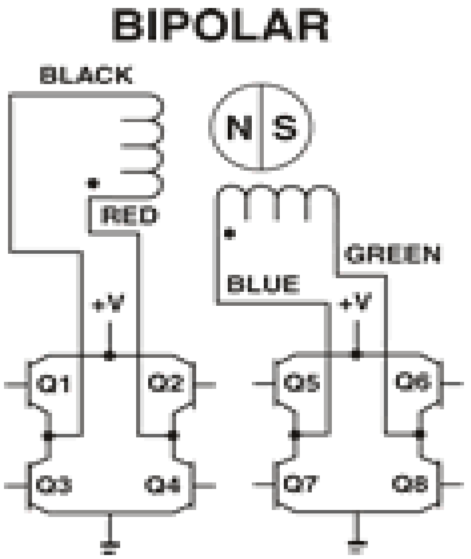
Unipolar stepper (5, 6 or 8 wires)

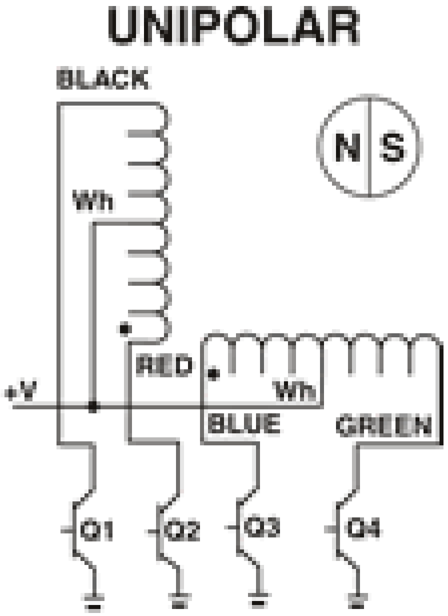
http://www.haydonkerk.com/Resources/StepperMotorTheory/tabid/192/Default.aspx

Motors: Stepper motors

Unipolar vs bipolar windings:



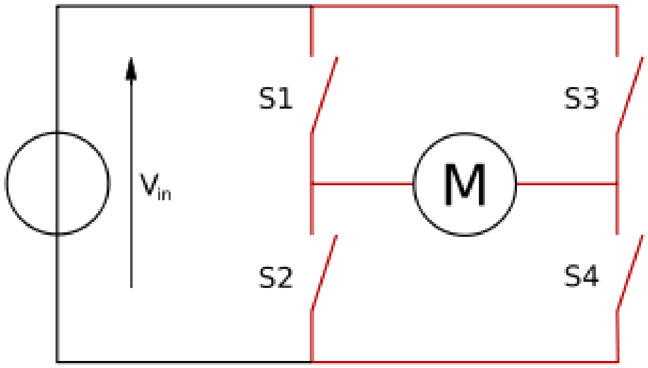




http://www.haydonkerk.com/Resources/StepperMotorTheory/tabid/192/Default.aspx

Driving Motors: H-bridge

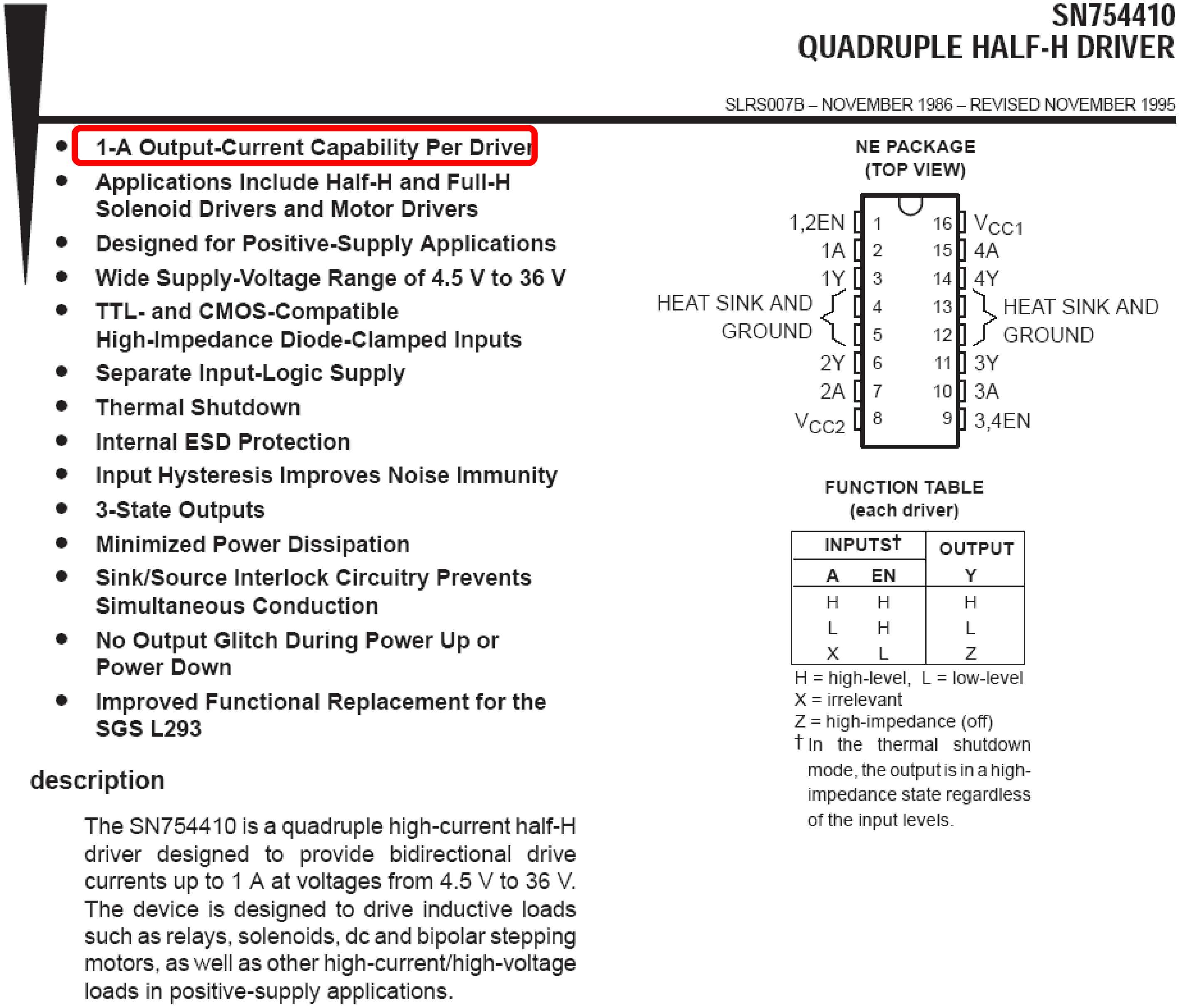
To drive a dc motor in either direction with a single power supply, close S1 and S4 OR S2 and S3.



http://en.wikipedia.org/wiki/File:H_bridge.svg

The switches are often transistors: bipolar or MOSFETs

Driving Motors: H-bridge



SN754410
QUADRUPLE HALF-H DRIVER

SLRS007B – NOVEMBER 1986 – REVISED NOVEMBER 1995

- **1-A Output-Current Capability Per Driver**
- **Applications Include Half-H and Full-H Solenoid Drivers and Motor Drivers**
- **Designed for Positive-Supply Applications**
- **Wide Supply-Voltage Range of 4.5 V to 36 V**
- **TTL- and CMOS-Compatible High-Impedance Diode-Clamped Inputs**
- **Separate Input-Logic Supply**
- **Thermal Shutdown**
- **Internal ESD Protection**
- **Input Hysteresis Improves Noise Immunity**
- **3-State Outputs**
- **Minimized Power Dissipation**
- **Sink/Source Interlock Circuitry Prevents Simultaneous Conduction**
- **No Output Glitch During Power Up or Power Down**
- **Improved Functional Replacement for the SGS L293**

NE PACKAGE
(TOP VIEW)

FUNCTION TABLE
(each driver)

INPUTS†		OUTPUT
A	**EN**	**Y**
H	H	H
L	H	L
X	L	Z

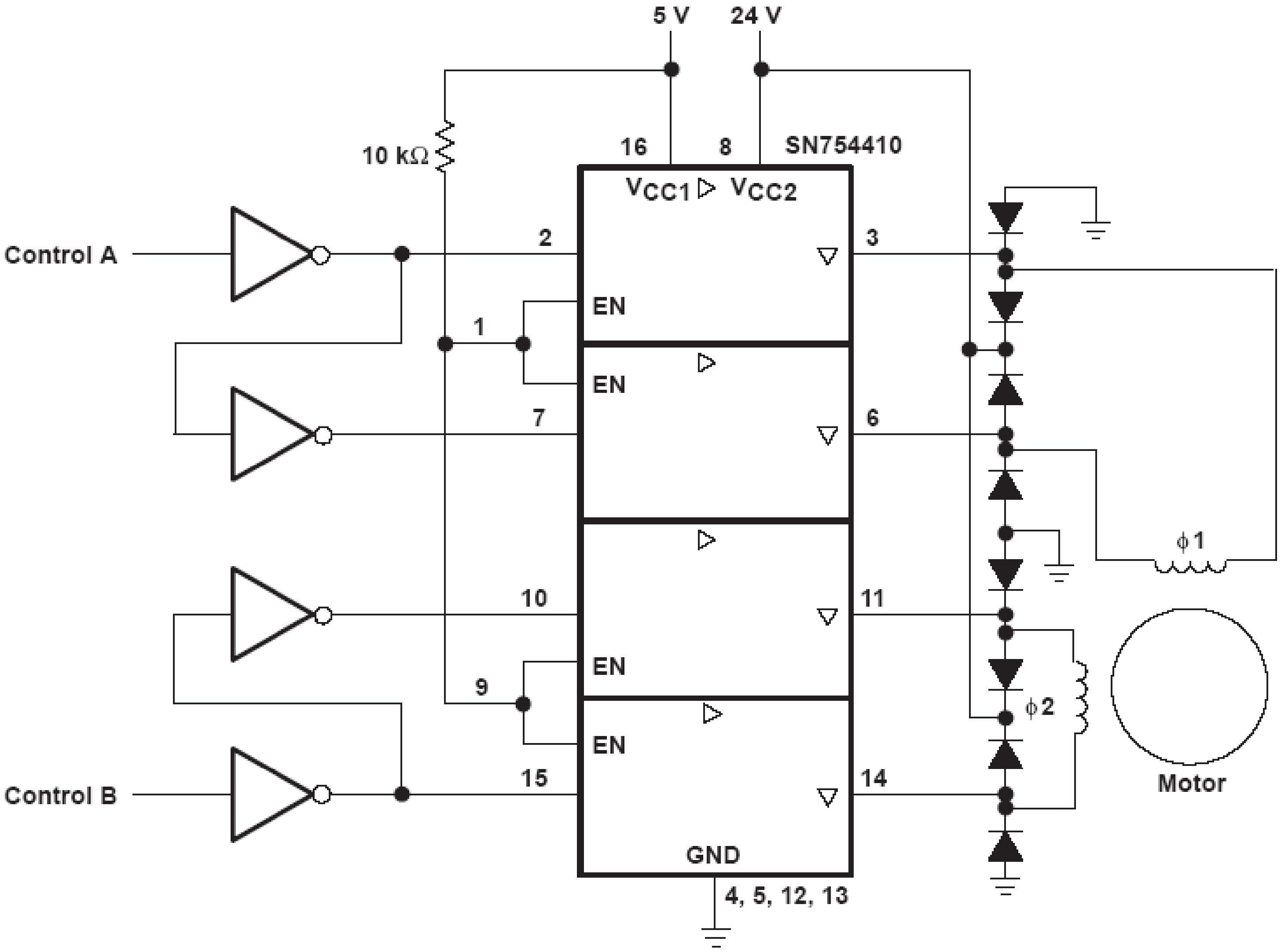
H = high-level, L = low-level
X = irrelevant
Z = high-impedance (off)
† In the thermal shutdown mode, the output is in a high-impedance state regardless of the input levels.

description

The SN754410 is a quadruple high-current half-H driver designed to provide bidirectional drive currents up to 1 A at voltages from 4.5 V to 36 V. The device is designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications.

Driving Motors: H-bridge

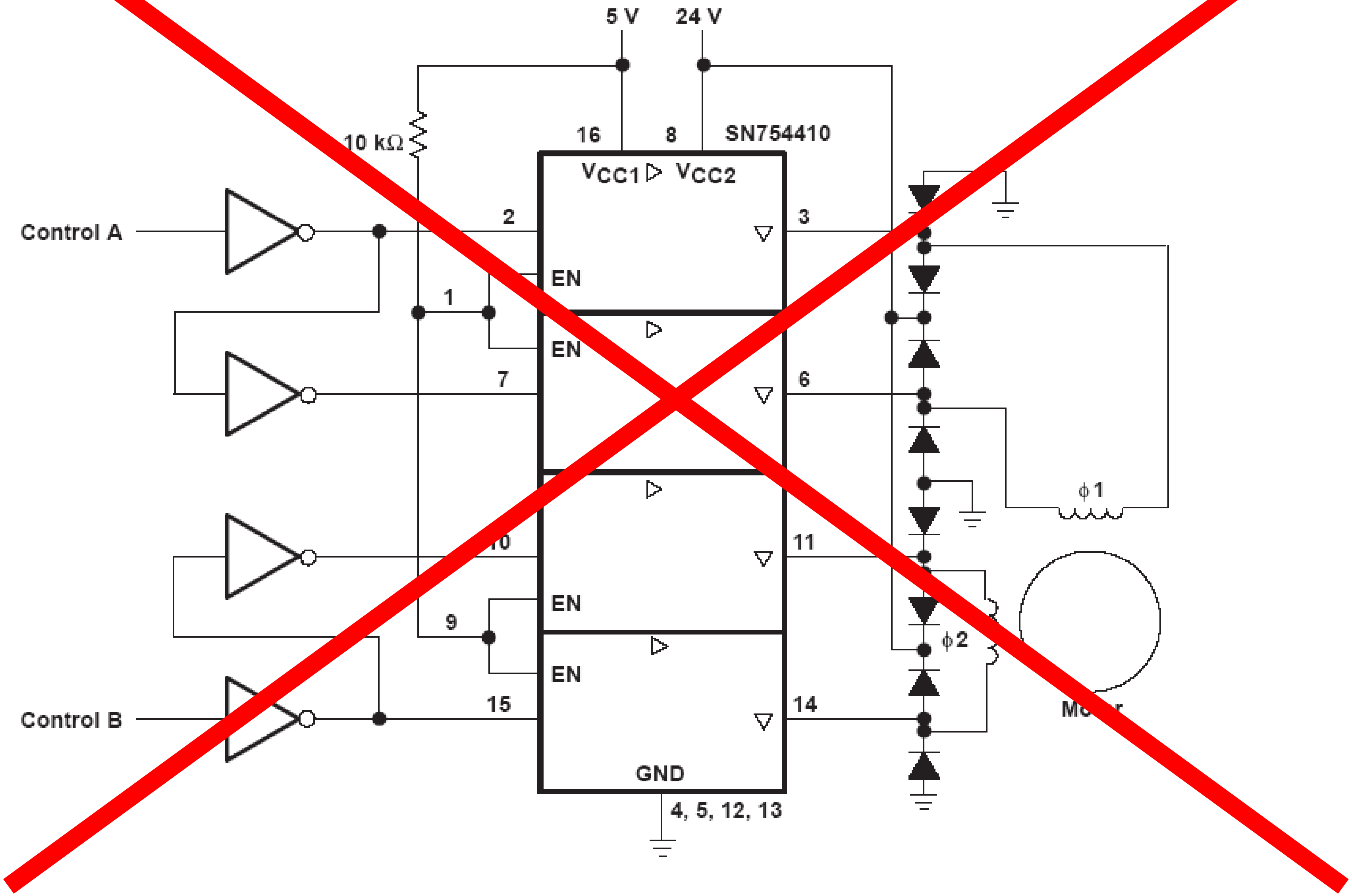
5 -



This is for a bipolar stepper motor (or a unipolar stepper ignoring the center taps

Driving Motors: H-bridge

5 -

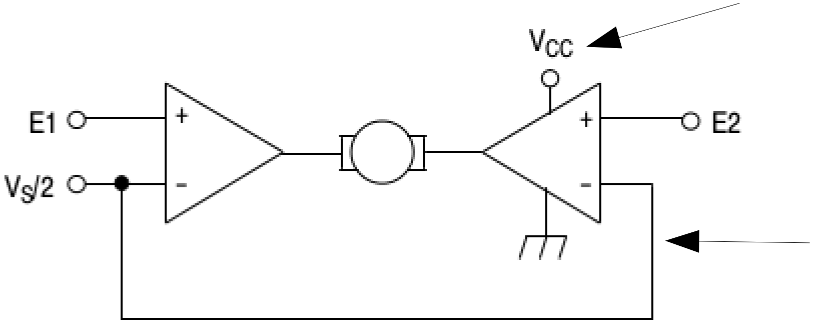


This is for a bipolar stepper motor (or a unipolar stepper ignoring the center taps

Driving Motors: high current op-amp

dual op-amp with 1A output current
and thermal protection: TCA0372

eg 6V, 12V, 15V for motor



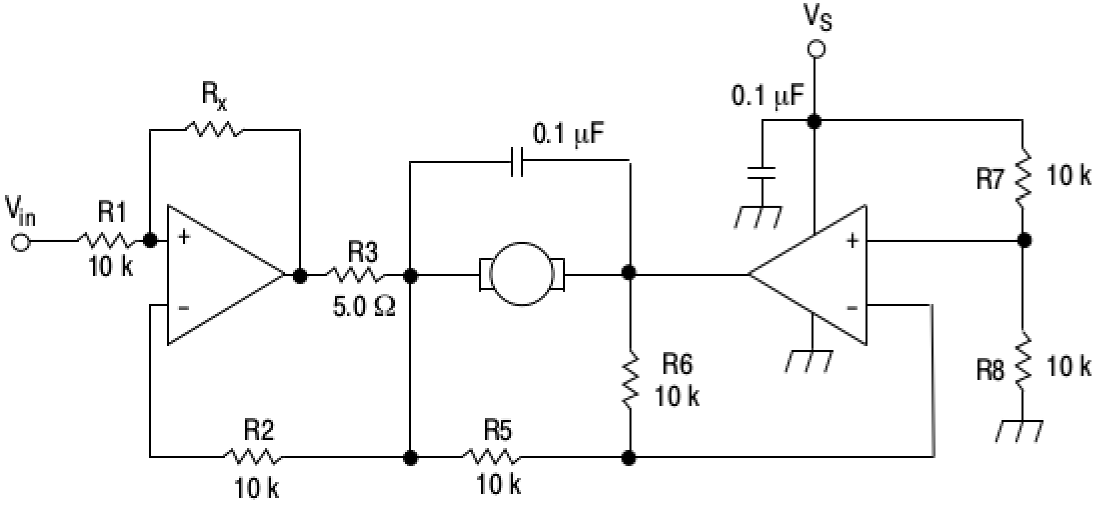
logic threshold

V_S = Logic Supply Voltage
Must Have $V_{CC} > V_S$
E1, E2 = Logic Inputs

Figure 9. Bidirectional DC Motor Control with Microprocessor–Compatible Inputs

Driving Motors: high current op-amp

dual op-amp with 1A output current
and thermal protection: TCA0372



For circuit stability, ensure that $R_x > \dfrac{2R3 \cdot R1}{R_M}$ where, R_M = internal resistance of motor.

The voltage available at the terminals of the motor is: $V_M = 2\,(V_1 - \dfrac{V_S}{2}) + |R_o| \cdot I_M$

where, $|R_o| = \dfrac{2R3 \cdot R1}{R_X}$ and I_M is the motor current.

Figure 10. Bidirectional Speed Control of DC Motors

Where to find parts?

- In town: Main Electronics/Lee's electronics (Main & ~28th)
- In town: RP Electronics (Rupert st, near Broadway)
- In town: Active Electronics 3695 E 1st
- Digikey/Newark (fast, but shipping costs)
- www.sparkfun.com, www.robotshop.ca, www.bc-robotics.com, www.adafruit.com
- ebay, dx.com, aliexpress (cheap, but very slow shipping).

Beware of buying bare surface mount devices! Get
DIP packages or 'breakout' mounted.