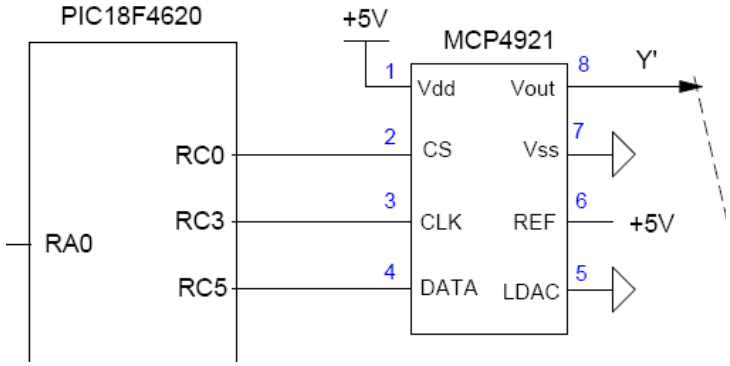
More Fun with D/A Converters

D/A with a PIC Microcontroller (recap)



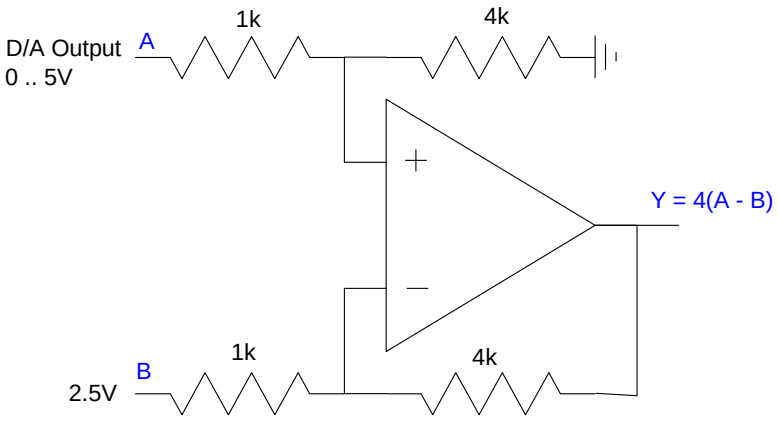
A subroutine to drive this chip follows:

```
  void D2A(unsigned int X)
  {
     unsigned char i;

     TRISC0 = 0;
     TRISC3 = 0;
     TRISC5 = 0;

  // Add 0011 to the first four bits to set up the D/A

     X = X & 0x0FFF;
     X = X + 0x3000;

     RC0 = 1;
     RC3 = 1;

  // CS goes low to select the D/A chip
     RC0 = 0;

  // Send out 16 bits of data
     for (i=0; i<16; i++) {
        if (X & 0x8000) RC5 = 1; else RC5 = 0;
        RC3 = 0;
        X = X << 1;
        RC3 = 1;
        }

  // CS goes high to terminate the communicaitons
     RC0 = 1;
  }
```

Electronic Sine Wave Generator

So far, we've been driving a speaker with a square wave when making an electronic piano. This results in a harsh buzzing sound. For a clean sound, output a sine wave. To do this, first, approximate a sine wave with N data points.

Assume for example we want the sine wave to go from -2V to +2V. Using an instrumentation amplifier



Instrumentation Ampliifier to convert 0..5V to -10 .. +10V

you get:

Number to D/A	D/A Output	Circuit Output
0	0V	-10V
4,095	5V	+10V

The output voltage is related to the number you send to the D/A as

$$Volts = \left(\frac{D/A}{4095}\right) \cdot 20V - 10V$$

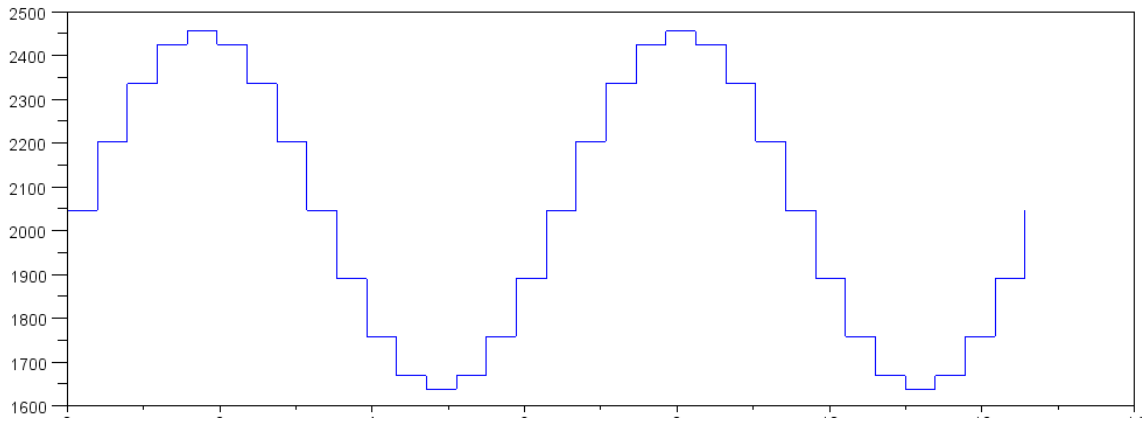
- To output -2V, you need to send the number 1638
- To output +2V, you need to send the number 2457

Let's use 16 points to approximate a sine wave. Use Matlab to generate a sine wave which goes from 1638 to 2457

```
-->t = [1:16]' / 16 * 2 * pi;
-->y = sin(t) * 409 + 2047;
-->y = round(y);

    2204.
    2336.
    2425.
    2456.
    2425.
    2336.
    2204.
    2047.
    1890.
    1758.
    1669.
```

```
1638.
1669.
1758.
1890.
2047.
```

This looks like the following when you send these voltages to the D/A



16-Point approximation to a sine wave

It's not a perfect sine wave. To do better, more points would help - but more points means the PIC will have to output numbers to the D/A that much faster.

To play a 220Hz sine wave,

One cycle = 1/220 second (4.54ms)

There are 16 D/A calls per cycle (we're representing a sine wave with 16 points)

Each D/A call = 286.1us

From before, when we wrote a wait routine, we found that counting to 620 with an integer takes about 1ms. 286.1us should require counting to 177

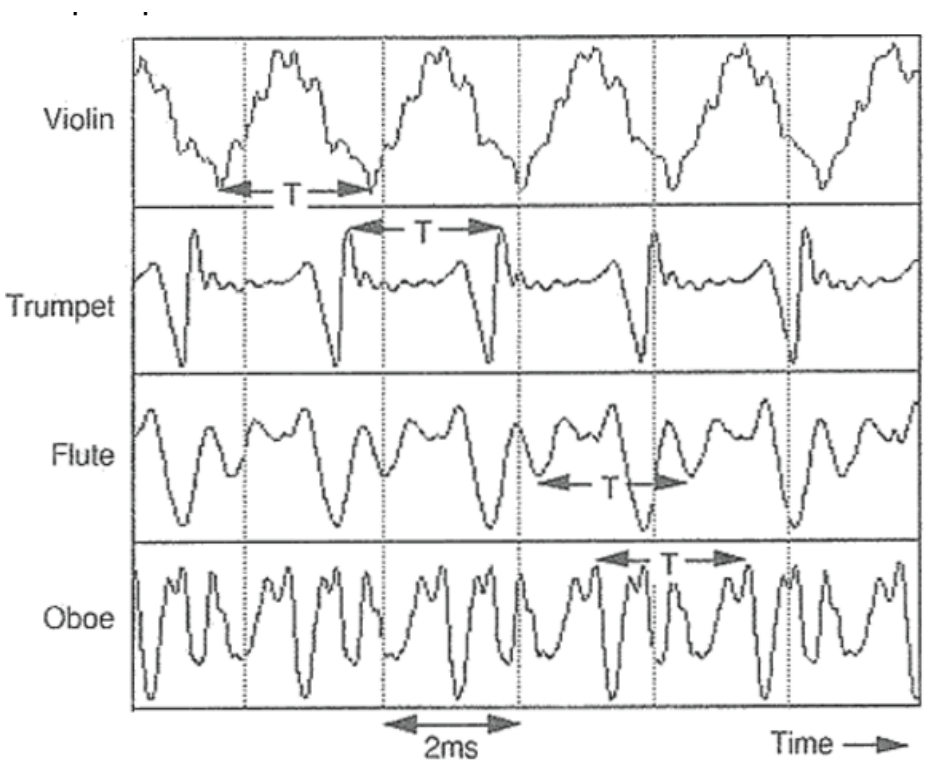
$$N = \left(\frac{286.1\mu s}{1ms}\right)620 = 177$$

The following code should generate a 220Hz sine wave:

```
const unsigned int TABLE[16] = [2204, 2336, 2425, 2456, 2425, 2336, 2204, 2047, 1890,
1758, 1669, 1638, 1669, 1758, 1890, 2047];

// in the main routine
   unsigned int i, j;

   while(1) {
      i = (i + 1) % 16;
      D2A(TABLE[i]);
      for(j=0; j<177; j++);
      }
```

Electronic Tuba

Note that if you change the look-up table, you change the signal sent to the speaker. The signal determines what type of instrument you're mimicking:



http://www.feilding.net/sfuad/musi3012-01/html/lectures/009_hearing_IV.htm

Analog Voltage Output:

* Control the speed of a DC servo motor (voltage = speed)

With a D/A, a PIC can output 0..5V with 4095 steps. With this, you can drive a DC motor at 0..20V with 4095 steps.

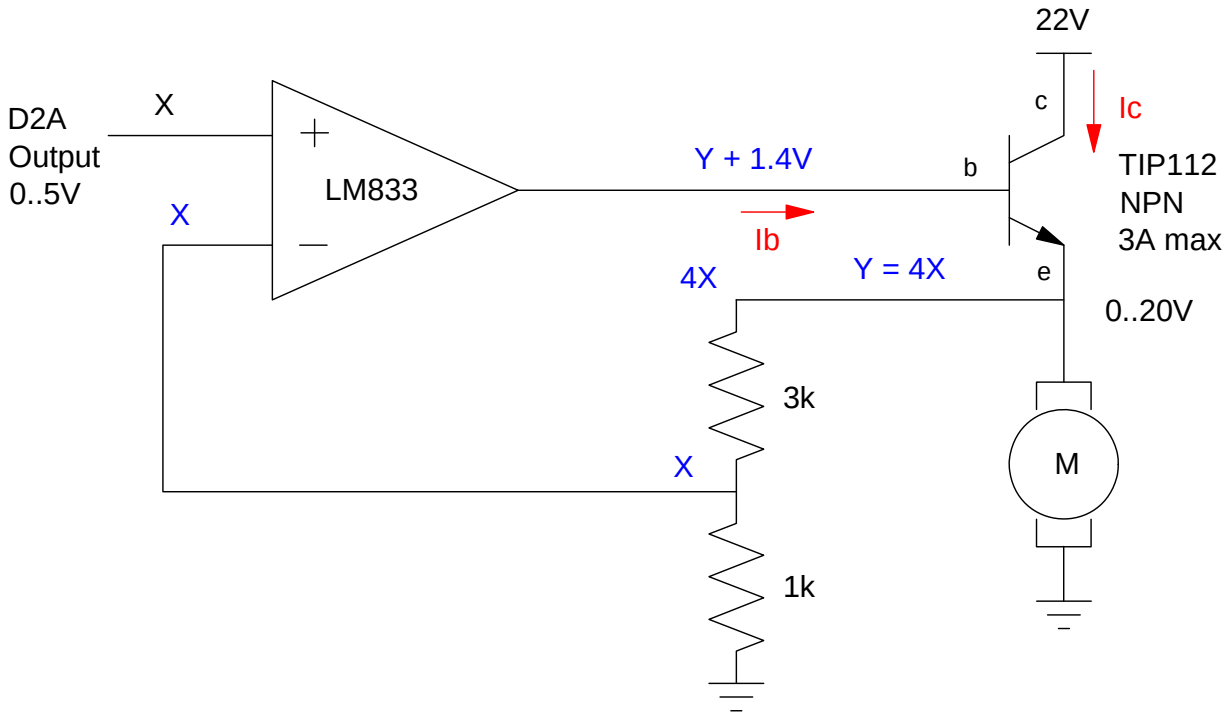
Hardware:

- To amplify the voltage 4x (0..5V becomes 0..20V), use a non-inverting amplifier.
- To amplify the current, use a power transistor (TIP112)

With negative feedback, V+ equals V-. For this to happen, the output must be 4x the input.

The op-amp's output is whatever it takes to make V+ equal to V-. With the 1.4V drop across the transistor's base to emitter junction, this results in the op-amp outputting 4 times the input, plus 1.4V (not that we really care - but it does).

The transistor provides a current gain of 1000. This means that to drive a load of 3A, the op-amp only needs to source 3mA - something an LM833 is capable of doing.



With this circuit, you can vary the voltage to the motor (and hence the speed) from 0V to 20V with 4095 steps using a PIC microcontroller.

Analog Current Output:

* Control the brightness of an LED (current = lumens)

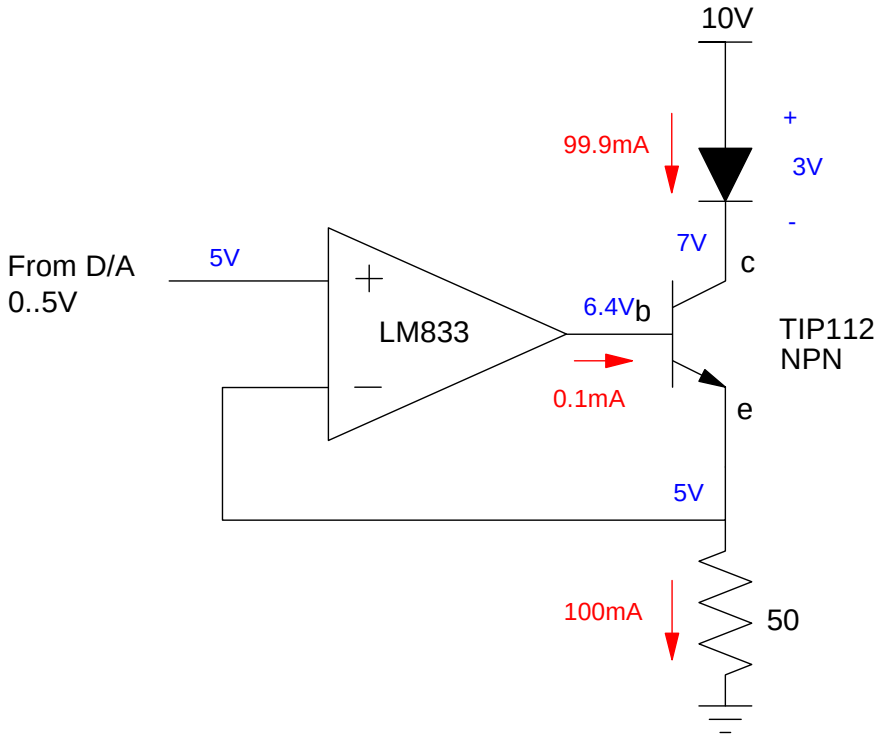
* Control the torque of a DC servo motor (current = torque)

A slight variation on this circuit is a current amplifier. Again, an op-amp with negative feedback to force V+ to equal V-. To control current, place a resistor in series with the diode. Add a resistor to set the maximum current (100mA) when X is its maximum voltage (5V)

$$R = \frac{5V}{100mA} = 50\Omega$$

Add a transistor to amplify the current from the op-amp. Using a TIP112 (with a current gain of 1000) results in the op-amp having to output 0.1mA when driving 100mA to the load - something an LM833 is capable of doing.

Place the diode in series with the 50 Ohm resistor so that any current going through R also goes through the diode (almost: the base current splits of 1/1000th of the current to the 50 ohm resistor).



With this circuit, you can control the current to the LED from 0 to 100mA with 4095 steps.

Also note: if you replace the diode with a DC motor, you're controlling the current to the motor (torque) rather than voltage (speed).

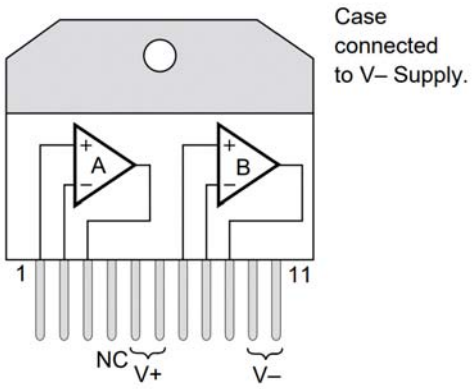
Also also: Back in EE 206, you used current sources. That's what this circuit is: the current to the load is set by the voltage at X.

DC Servo Motor Control:

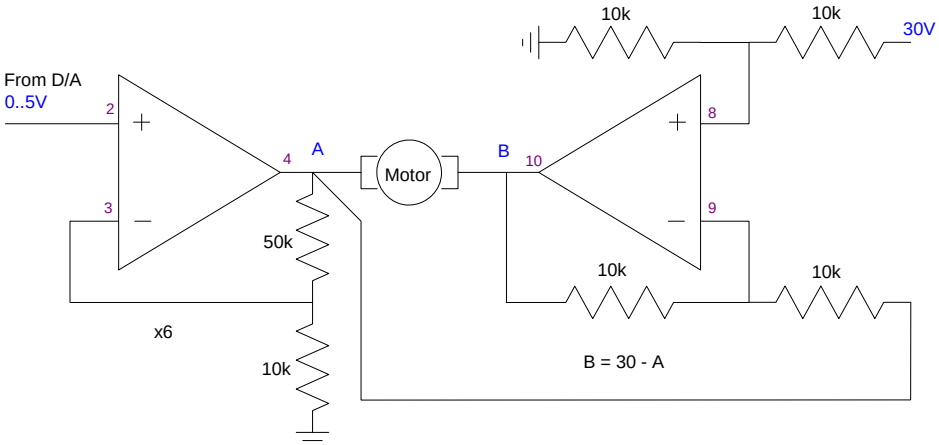
Suppose you want to control the speed of a DC servo motor. The first thing you need is a power amplifier. Two options are

- OPA2544 Dual Op-Amp ($22 from Digikey)
- Advanced Motion Controls 30A8T ($58 on ebay)

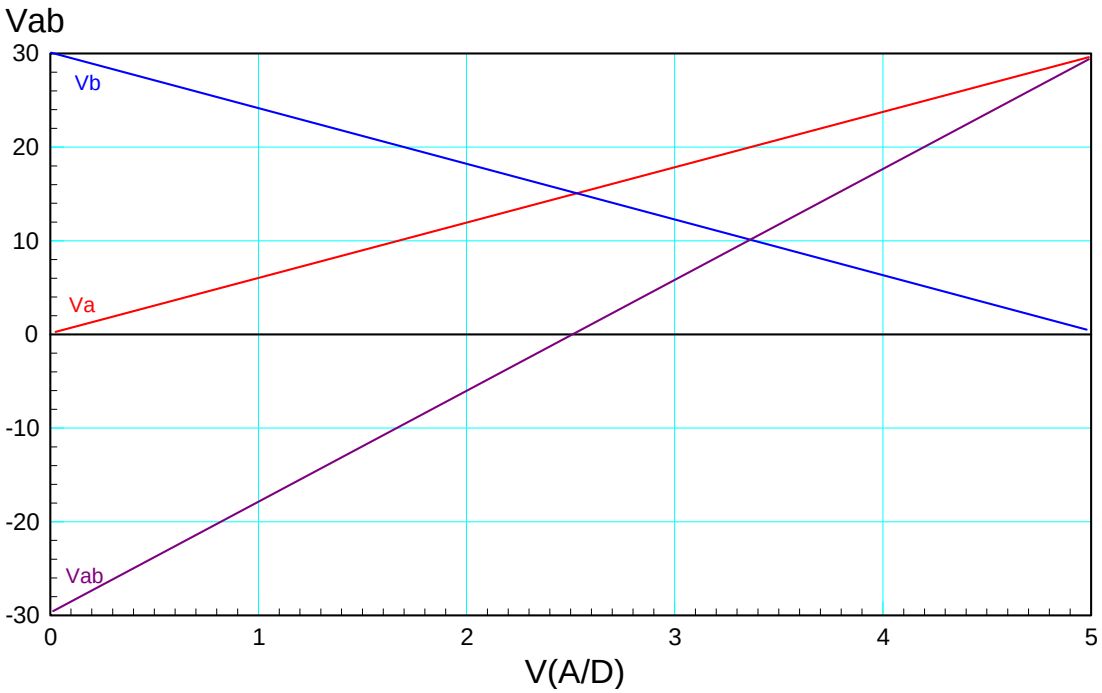
Option 1: OPA2544: This chip is a dual op-amp capable of +/- 35V adn 4A.



To connect to a DC servo motor, use the following circuit



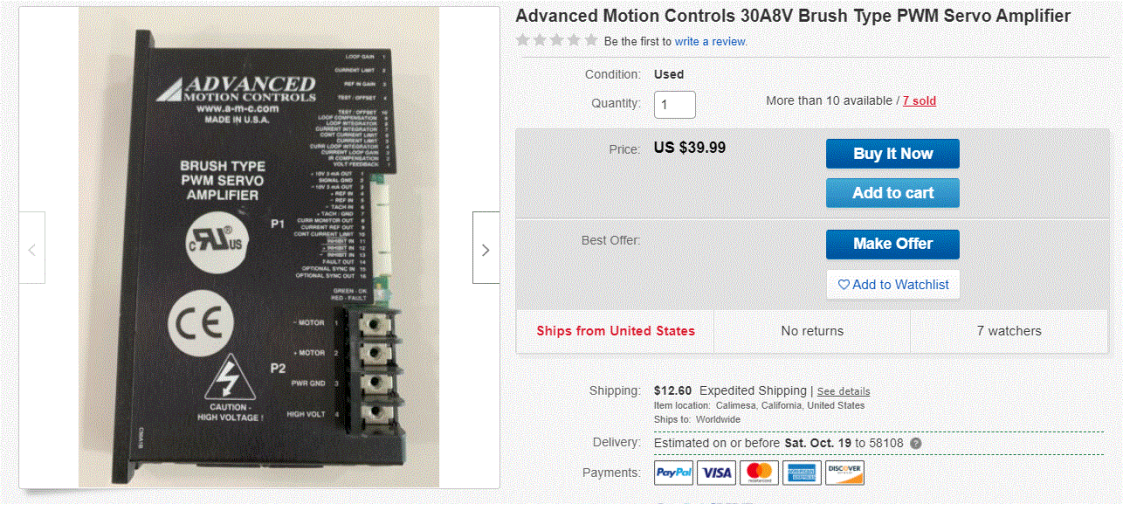
As the D/A outputs 0..5V, the voltage Vab goes from -30V to +30V driving the speed of the motor from full reverse to full forward.



Note the following:

- You only need a +30V supply to drive the motor at -30V to +30V analog
- Neither Va nor Vb is ground. They vary from 0 .. +30V such that the difference (Vab) goes from -30V to +30V.
- Don't tie either Va or Vb to ground. The op-amp won't like that.

Option #2: AMD 30A8T (better option)



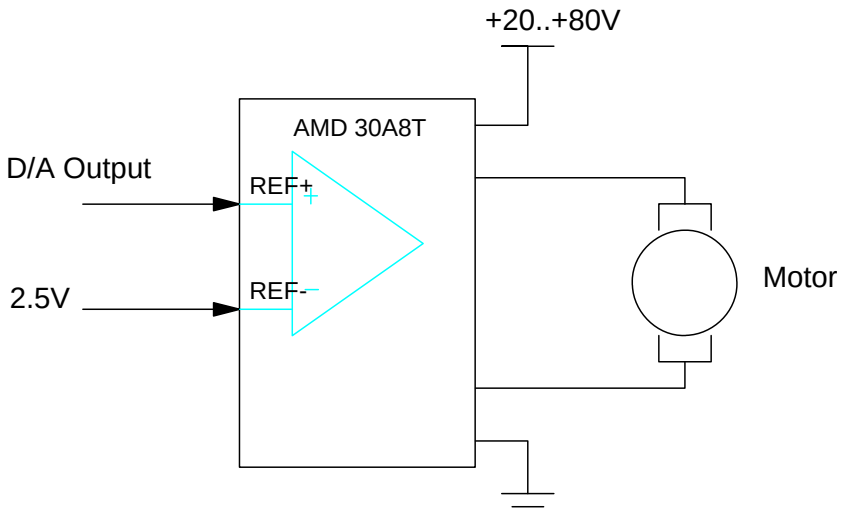
ebay: Advanced Motion Controls 30A8T. Typical price on ebay os $25 to $100 each

Another option is to use an Advanced Motion Controls 30A8T. This is really the same thing as an OPA2544, but better

- Voltage range: +20V to +80V
- Current Limit: Up to 20A
- Higher efficiency (data sheets say 90%)
- Protection circuitry (doesn't die as easily)

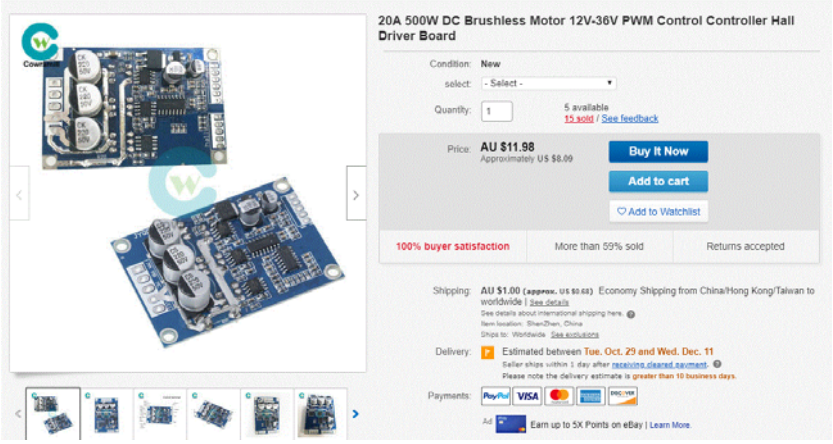
Just connect

- REF+ to the D/A output (0..5V)
- REF- to 2.5V
- Adjust the gain and offset so that you get +30V at+5V, -30V at -5V



Hardware connections for an AMD 30A8T

Simiarly, if you want to drive a 3-phase AC synchronous motor, you need a variable frequency drive. These are available on ebay for about $10 each

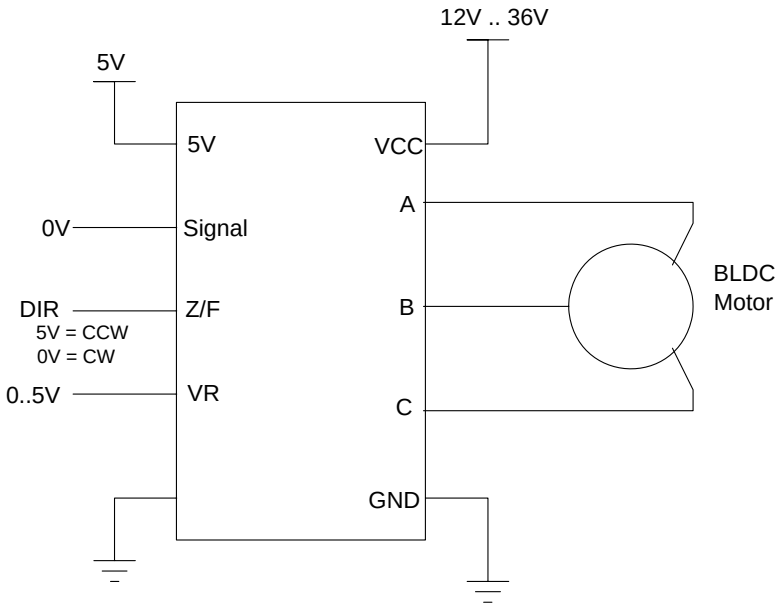


One of many ebay listings for a BLDC driver

These boards

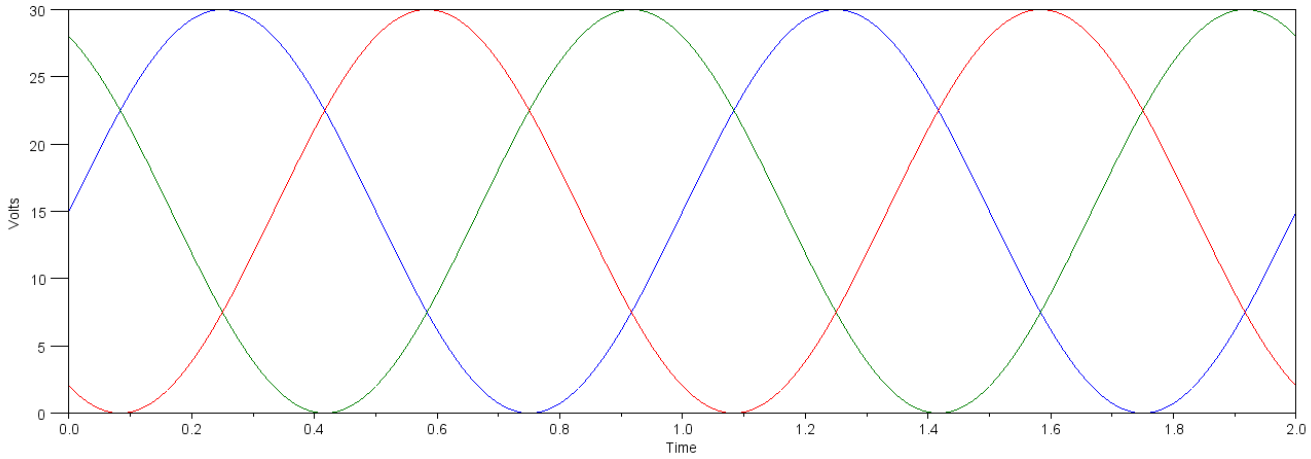
- Take an analog input (0..5V), and
- Generate 3-phase AC waveforms
- With a frequency (i.e. speed) proportional to the input voltage

The hardware connections are as follows:



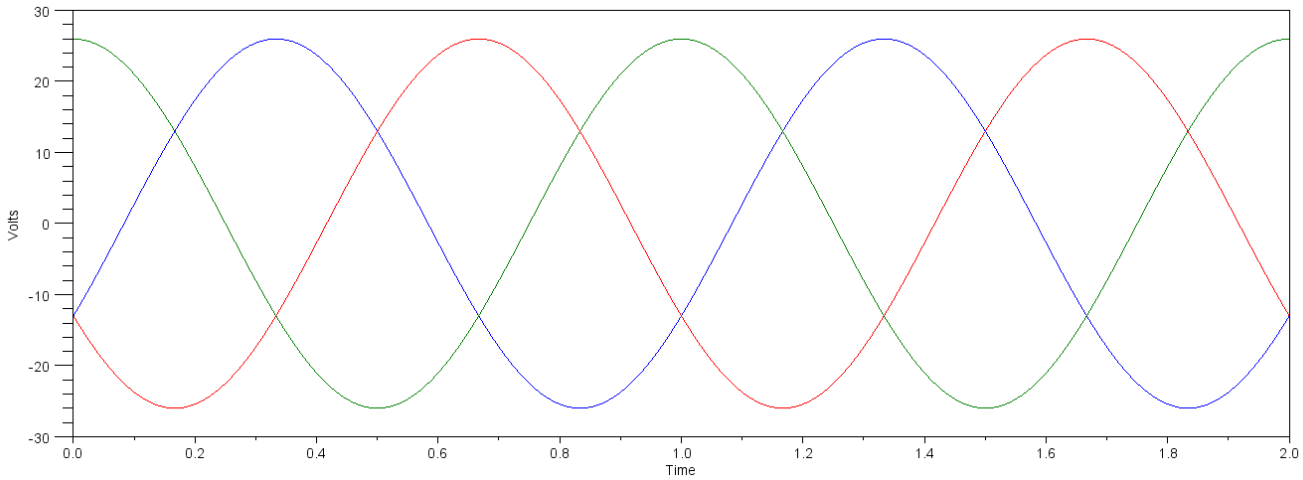
hardware connections for driving a BLDC motor (i.e. a 3-phase AC motor)

If you look at the votlages on an oscilloscope, the signals at Va, Vb, and Vc look like the following:



Voltages Va, Vb, and Vc. The frequency is proportional to the input voltage at Z/F

The difference in voltages (Vab, Vbc, Vca) then are the desired 3-phase AC signals



Voltages Vab, Vbc, Vca. The frequency is proprotional to the input voltage at Z/F