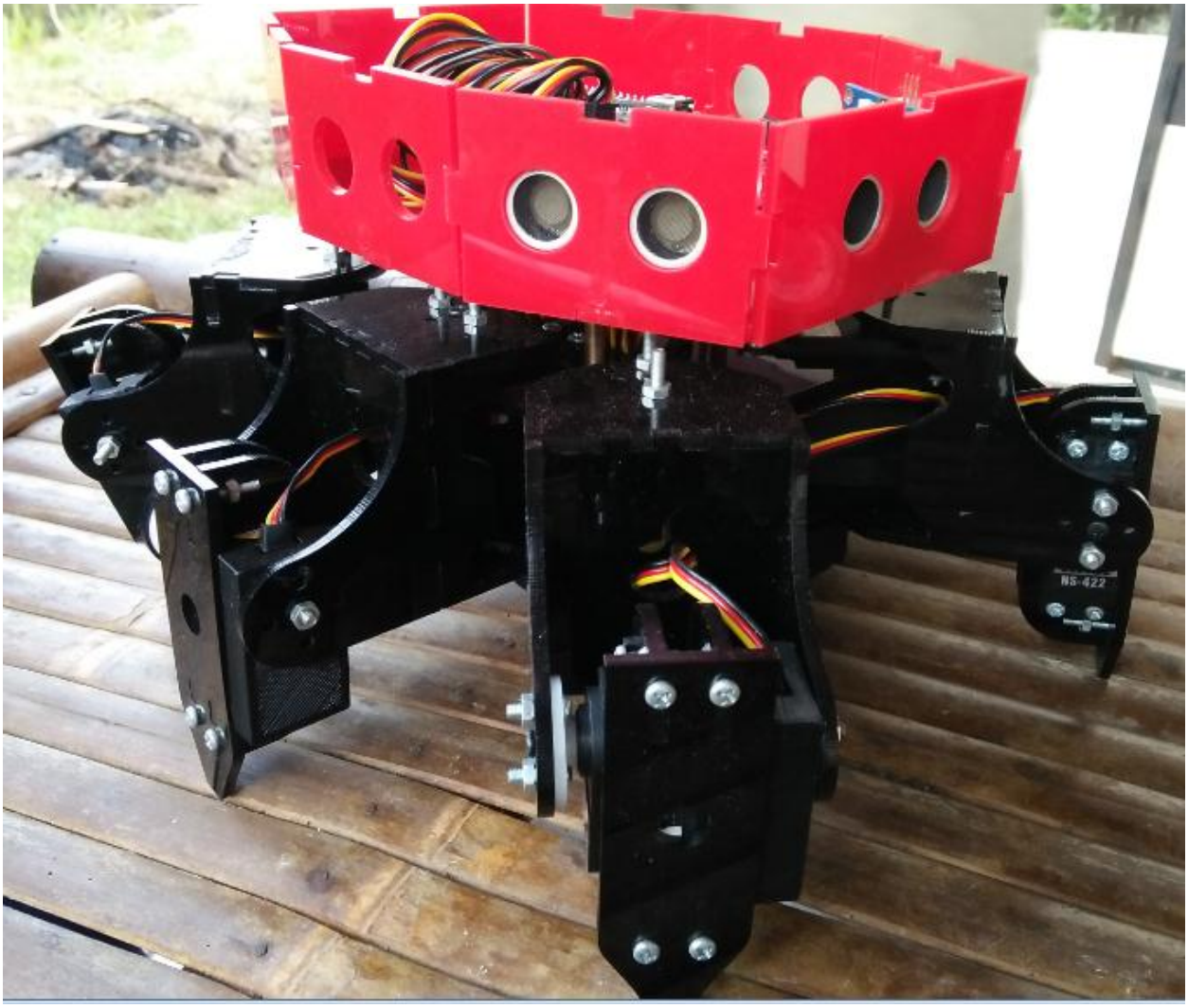
LAMPIRAN

Program Untuk Pergerakan Kaki Robot Maju

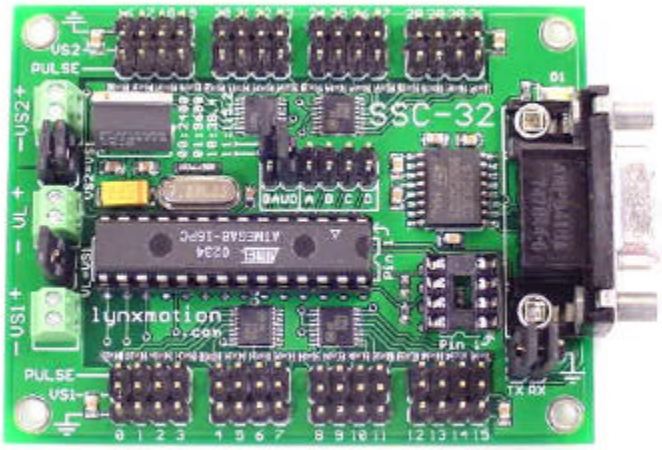
```
  inverse_dg_ssc
}

void maju() {
  //step 1 angkat maju

  invers_kinematik(3, 3);
  //kaki 1 angkat
  servo2 = map((90+sudut[0]),0,180,SERVOMIN,SERVOMAX);
  servo1 = map((90 + sudut[1]),0,180,SERVOMIN,SERVOMAX);

  //kaki 2 turun
  servo4 = map(70,0,180,SERVOMIN,SERVOMAX);
  servo3 = map((90 - sudut[1]),0,180,SERVOMIN,SERVOMAX);

  //kaki 3 angkat
  servo6 = map((90+sudut[0]),0,180,SERVOMIN,SERVOMAX);
  servo5 = map((90 + sudut[1]),0,180,SERVOMIN,SERVOMAX);

  //kaki 4 turun
  servo8 = map(70,0,180,SERVOMIN,SERVOMAX);
  servo7 = map((90 + sudut[1]),0,180,SERVOMIN,SERVOMAX);

  //kaki 5 angkat
  servo10 = map((180-sudut[0]),0,180,SERVOMIN,SERVOMAX);
  servo9 = map((90 - sudut[1]),0,180,SERVOMIN,SERVOMAX);

  //kaki 6 turun
  servo12 = map(70,0,180,SERVOMIN,SERVOMAX);
```

Robot Jadi



SSC-32 Ver 2.0

Manual written for firmware
version SSC32-1.06XE
Range is 0.50mS to 2.50mS



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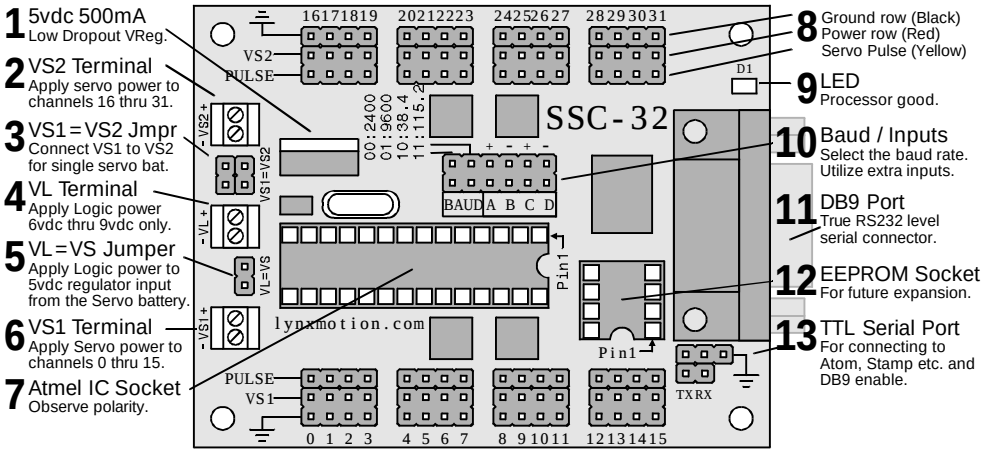
Things that go Boom!

Caution! Read this quick start guide completely before wiring and applying power to the board! Errors in wiring can damage the SSC-32 board, Atmel or EEPROM Chip, and any attached servos or peripherals.

Caution! Never reverse the power coming in to the board. Make sure the black wire goes to (-) ground, and the red wire goes to (+) Vlogic, or Vservo. Never connect peripherals when the board is powered on.

Caution! The onboard regulator can provide 250mA total. This includes the microcontroller chip, the onboard LEDs, and any attached peripherals. Drawing too much current can cause the regulator to overheat.



1 The Low Dropout regulator will provide 5vdc out with as little as 5.5vdc coming in. This is important when operating your robot from a battery. It can accept a maximum of 9vdc in. The regulator is rated for 500mA, but we are de-rating it to 250mA to prevent the regulator from getting too hot.

2 This terminal connects power to servo channels 16 thru 31. Apply 4.8vdc to 7.2vdc for normal servos. Apply 4.8vdc to 6.0vdc when using micro servos. Do not exceed 7.4vdc (measure it) when using HSR-5995TG servos!

Board	Input
VS2 + VS2 -	RED BLACK

3 These jumpers are used to connect VS1 to VS2. Use this option when you are powering all servos from the same battery. Use both jumpers.

4 This is the Electronics Power Input. It is also referred to as the Logic Voltage, or VL. This input is normally used with a 9vdc battery connector to provide power to the ICs and anything connected to the 5vdc lines on the board. This input is used to isolate the logic from the Servo Power Input.

Board	Input
VL + VL -	RED BLACK

5 This jumper allows powering the microcontroller and support circuitry from the servo power supply. This requires at least 6vdc to operate correctly. If the microcontroller resets when many servos are moving it may be necessary to power the microcontroller separately using the VL input. A 9vdc battery works nicely for this.

6 This terminal connects power to servo channels 0 thru 15. Apply 4.8vdc to 7.2vdc for normal servos. Apply 4.8vdc to 6.0vdc when using micro servos. Do not exceed 7.4vdc (measure it) when using HSR-5995TG servos!

Board	Input
VL1 + VL1 -	RED BLACK

7 This is where the Atmel IC chip goes. Be careful to insert it with Pin 1 in the upper right corner as pictured. Take care not to bend the pins.

8 This is where you connect the servos or other output devices. Use caution and remove power when connecting anything to the I/O bus.

9 This is the Processor Good LED. It will light steady when power is applied and will remain lit until the processor has received a valid serial command. It will then go out and then blink whenever it is receiving serial data. Note, this feature may not be used on user-submitted firmware for the SSC-32.

10 The two BAUD inputs allow configuring the baud rate. Please see the examples below. The ABCD inputs have both static and latching support. The inputs have internal weak (50k) pullups that are used when a Read Digital Input command is used. A normally open switch connected from the input to ground will work fine. These features may not be used on user-submitted firmware for the SSC-32.

Jumpers	Baud Rate
0 0	2400
0 1	9600
1 0	38.4k
1 1	115.2k

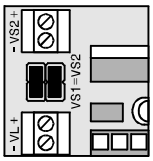
11 Simply plug a straight-through M/F DB9 cable from this plug to a free 9 pin serial port on your PC for receiving servo positioning data. Alternately a USB-to-serial adaptor will work well.

12 This is an 8 pin EEPROM socket. It is not used in this version of the firmware, although it will be used in future versions.

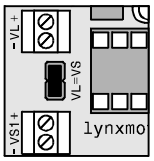
13 This is the TTL serial port or DB9 serial port enable. Install two jumpers as illustrated below to enable the DB9 port. Install wire connectors to utilize TTL serial communication from a host microcontroller.

Shorting Bar Jumpers and Connectors at a glance

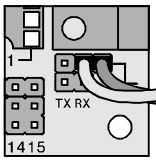
Applies VS1 to VS2.



Applies VS to VL.

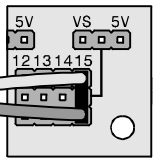


TTL Serial com. SSC-32 side...

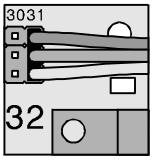


DC-01

TTL Serial com. Bot Board side...

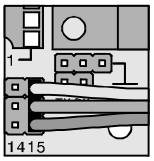


Example servo connection 16-31.



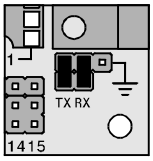
Black
Red
Yellow

Example servo connection 0-15.

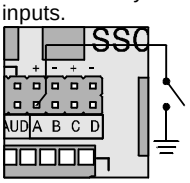


Yellow
Red
Black

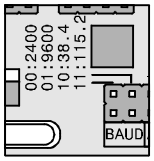
DB9 enable for PC use.



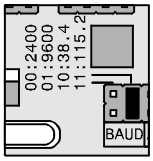
ABCD auxiliary inputs.



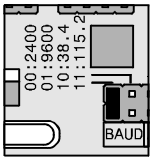
Baud rate 2400.



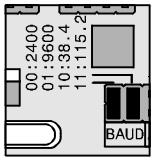
Baud rate 9600.



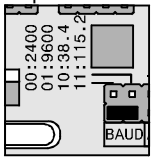
Baud rate 38.4k for Basic Atom use.



Baud rate 115.2k for PC use.



Update the Atmel chip firmware.



Caution! Don't do this if you don't know what you're doing. Connecting this jumper can overwrite the Atmel chip's firmware.

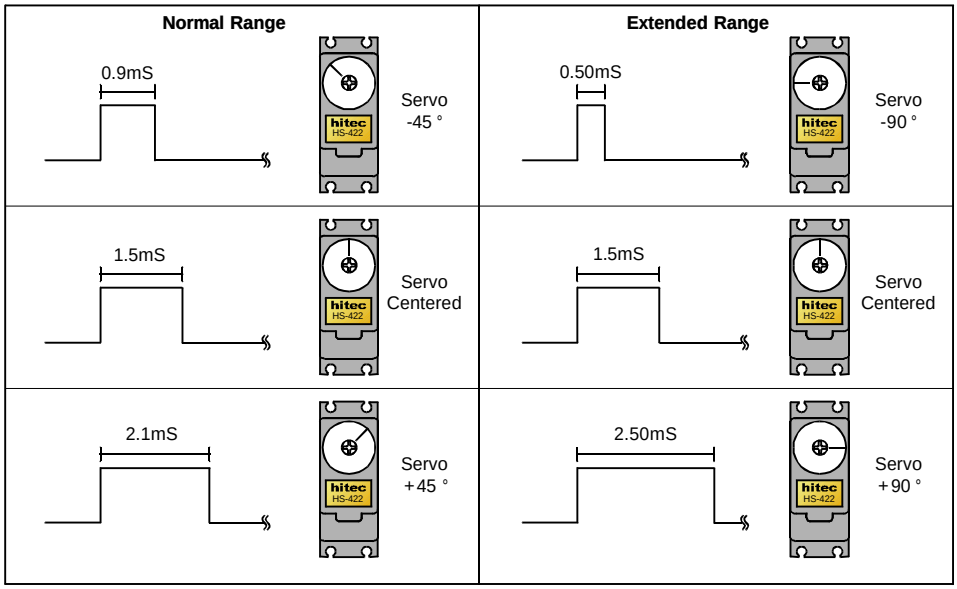
Getting Started

What is a Servo?
Before we illustrate how to use the servo controller we need to explain what a servo is, and define the control methodology.

Pulse-proportional servos are designed for use in radio-controlled (R/C) cars, boats and planes. They provide precise control for steering, throttle, rudder, etc. using a signal that is easy to transmit and receive. The signal consists of positive going pulses ranging from 0.9 to 2.1mS (milliseconds) long, repeated 50 times a second (every 20mS). The servo positions its output shaft in proportion to the width of the pulse, as shown below.

In radio-control applications, a servo needs no more than a 90° range of motion, since it is usually driving a crank mechanism that can't move more than 90°. So when you send pulses within the manufacturer-specified range of 0.9 to 2.1mS, you get around 90° range of motion.

Most servos have more than 90° of mechanical range. In fact, most servos can move up to 180° of rotation. However, some servos can be damaged when commanded past their mechanical limitations. The SSC-32 lets you use this extra range. A position value of 500 corresponds to 0.50mS pulse, and a position value of 2500 corresponds to a 2.50mS pulse. A one unit change in position value produces a 1uS (microsecond) change in pulse width. The positioning resolution is 0.09°/unit (180°/2000). From here on, the term pulse width and position are the same.



Remember that some servos may not be able to move the entire 180° range. Use care when testing servos. Move to the extreme left or right slowly, looking for a point when additional positioning values no longer result in additional servo output shaft movement. When this value is found, put it as a limit in your program to prevent damaging the servo. Generally, micro servos are not able to move the entire 180° range.

What is Open Source?
It simply means we are distributing the source code for the bootloader and firmware. The goal is to have an affordable platform that many people will provide firmware for. It should also help many aspiring programmers learn some tricks. Anyone can use the source code to write specialized firmware, providing you allow Lynxmotion, Inc. to publish it for others to enjoy. The source code can not be used in a commercial product. As it is, this servo controller will outperform controllers costing two to three times as much. Having several "flavors" of the firmware will make this an even better value.

Command Formatting for the SSC-32

Command Types and Groups

1) Servo Movement.
2) Discrete Output.
3) Byte Output.
4) Query Movement Status.
5) Query Pulse Width.
6) Read Digital Inputs.
7) Read Analog Inputs.
8) 12 Servo Hexapod Gait Sequencer.
9) Query Hex Sequencer.
10) Get Version.
11) Go To Boot.
12) MiniSSC-II Compatibility.

With the exception of MiniSSC-II mode, all SSC-32 commands must end with a carriage return character (ASCII 13). Multiple commands of the same type can be issued simultaneously in a *Command Group*. All of the commands in a command group will be executed after the final carriage return is received. Commands of different types cannot be mixed in the same command group. In addition, numeric arguments to all SSC-32 commands must be ASCII strings of decimal numbers, e.g. "1234". Some commands accept negative numbers, e.g. "-5678". Programming examples will be provided. ASCII format is not case sensitive. Use as many bytes as required. Spaces, tabs, and line feeds are ignored.

Servo Move or Group Move:

<ch> P <pw> S <spd> ... # <ch> P <pw> S <spd> T <time> <cr>

<ch> = Channel number in decimal, 0 - 31.
<pw> = Pulse width in microseconds, 500 - 2500.
<spd> = Movement speed in uS per second for one channel. (Optional)
<time> = Time in mS for the entire move, affects all channels, 65535 max. (Optional)
<cr> = Carriage return character, ASCII 13. (Required to initiate action)
<esc> = Cancel the current command, ASCII 27.

Servo Move Example: "#5 P1600 S750 <cr>"

The example will move the servo on channel 5 to position 1600. It will move from its current position at a rate of 750uS per second until it reaches its commanded destination. For a better understanding of the speed argument consider that 1000uS of travel will result in around 90° of rotation. A speed value of 100uS per second means the servo will take 10 seconds to move 90°. Alternately a speed value of 2000uS per second equates to 500mS (half a second) to move 90°.

Servo Move Example: "#5 P1600 T1000 <cr>"

The example will move servo 5 to position 1600. It will take 1 second to complete the move regardless of how far the servo has to travel to reach the destination.

Servo Group Move Example: "#5 P1600 #10 P750 T2500 <cr>"

The example will move servo 5 to position 1600 and servo 10 to position 750. It will take 2.5 seconds to complete the move, even if one servo has farther to travel than another. The servos will both start and stop moving at the same time. This is a very powerful command. By commanding all of the legs in a walking robot with the Group Move it is easy to synchronize complex gaits. The same synchronized motion can benefit the control of a robotic arm as well.

You can combine the speed and time commands if desired. The speed for each servo will be calculated according to the following rules:

1. All channels will start and end the move simultaneously.
2. If a speed is specified for a servo, it will not move any faster than the speed specified (but it might move slower if the time command requires).
3. If a time is specified for the move, then the move will take at least the amount of time specified (but might take longer if the speed command requires).

Servo Move Example: "#5 P1600 #17 P750 S500 #2 P2250 T2000 <cr>"

The example provides 1600uS on ch5, 750uS on ch17, and 2250uS on ch2. The entire move will take at least 2 seconds, but ch17 will not move faster than 500uS per second. The actual time for the move will depend on the initial pulse width for ch17. Suppose ch17 starts at position 2000. Then it has to move 1250uS. Since it is limited to 500uS per second, it will require at least 2.5 seconds, so the entire move will take 2.5 seconds. On the other hand, if ch17 starts at position 1000, it only needs to move 250uS, which it can do in 0.5 seconds, so the entire move will take 2 seconds.

Important! Don't issue a speed or time command to the servo controller as the first instruction. It will assume it needs to start at 500uS and will zip there as quickly as possible. The first positioning command should be a normal "# <ch> P <pw>" command. Because the controller doesn't know where the servo is positioned on power up it has to be this way.

Pulse Offset:
<ch> PO <offset value> ... # <ch> PO <offset value> <cr>

<ch> = Channel number in decimal, 0 - 31.
<offset value> = 100 to -100 in uSeconds.
<cr> = Carriage return character, ASCII 13.

The servo channel will be offset by the amount indicated in offset value. This makes it easy to setup legs in a robot that do not allow mechanical calibration.

Discrete Output:
<ch> <lvl> ... # <ch> <lvl> <cr>

<ch> = Channel number in decimal, 0 - 31.
<lvl> = Logic level for the channel, either 'H' for High or 'L' for Low.
<cr> = Carriage return character, ASCII 13.

The channel will go to the level indicated within 20mS of receiving the carriage return.

Discrete Output Example: "#3H #4L <cr>"

This example will output a High (+5v) on channel 3 and a Low (0v) on channel 4.

Byte Output:
<bank> : <value> <cr>

<bank> = (0 = Pins 0-7, 1 = Pins 8-15, 2 = Pins 16-23, 3 = Pins 24-31.)
<value> = Decimal value to output to the selected bank (0-255). Bit 0 = LSB of bank.

This command allows 8 bits of binary data to be written at once. All pins of the bank are updated simultaneously. The banks will be updated within 20mS of receiving the CR.

Bank Output Example: "#3:123 <cr>"

This example will output the value 123 (decimal) to bank 3. 123 (dec) = 01111011 (bin), and bank 3 is pins 24-31. So this command will output a "0" to pins 26 and 31, and will output a "1" to all other pins.

Query Movement Status:
Q <cr>

This will return a "." if the previous move is complete, or a "+" if it is still in progress.

There will be a delay of 50uS to 5mS before the response is sent.

Query Pulse Width:
QP <arg> <cr>

This will return a single byte (in binary format) indicating the pulse width of the selected servo with a resolution of 10uS. For example, if the pulse width is 1500uS, the returned byte would be 150 (binary).

Multiple servos may be queried in the same command. The return value will be one byte per servo. There will be a delay of least 50uS to 5mS before the response is sent. Typically the response will be started within 100uS.

Read Digital Inputs:
A B C D AL BL CL DL <cr>

A, B, C, or D reads the value on the input as a binary value. It returns ASCII "0" if the input is a low (0v) or an ASCII "1" if the input is a high (+5v).

AL, BL, CL, or DL returns the value on the input as an ASCII "0" if the input is a low (0v) or if it has been low since the last *L command. It returns a high (+5v) if the input is a high and never went low since the last *L command. Simply stated it will return a low if the input ever goes low. Reading the status automatically resets the latch.

The ABCD inputs have a weak pullup (~50k) that is enabled when used as inputs. They are checked approximately every 1mS, and are debounced for approximately 15mS. The logic value for the read commands will not be changed until the input has been at the new logic level continuously for 15mS. The Read Digital Input Commands can be grouped in a single read, up to 8 values per read. They will return a string with one character per input with no spaces.

Read Digital Input Example: "A B C DL <cr>"

This example returns 4 characters with the values of A, B, C, and D-Latch. If A=0, B=1, C=1, and DL=0, the return value will be "0110".

Read Analog Inputs:
VA VB VC VD <cr>

VA, VB, VC, VD reads the value on the input as analog. It returns a single byte with the 8-bit (binary) value for the voltage on the pin.

When the ABCD inputs are used as analog inputs the internal pullup is disabled. The inputs are digitally filtered to reduce the effect of noise. The filtered values will settle to their final values within 8mS of a change. A return value of 0 represents 0vdc. A return value of 255 represents +4.98vdc. To convert the return value to a voltage multiply by 5/256. At power-up the ABCD inputs are configured for digital input with pullup. The first time a V* command is used, the pin will be converted to analog without pullup. The result of this first read will not return valid data.

Read Analog Input Example: "VA VB <cr>"

This example will return 2 bytes with the analog values of A and B. For example if the voltage on Pin A is 2vdc and Pin B is 3.5vdc, the return value will be the bytes 102 (binary) and 179 (binary).

12 Servo Hexapod Sequencer Commands:
LH <arg>, LM <arg>, LL <arg>
Set the value for the vertical servos on the left side of the hexapod. LH sets the high value, i.e. the pulse width to raise the leg to its maximum height; LM sets the mid value; and LL sets the low value. The valid range for the arguments is 500 to 2500uS.

RH <arg>, RM <arg>, RL <arg>
Set the value for the vertical servos on the right side of the hexapod. RH sets the high value, i.e. the pulse width to raise the leg to its maximum height; RM sets the mid value; and RL sets the low value. The valid range for the arguments is 500 to 2500uS.

VS <arg>
Sets the speed for movement of vertical servos. All vertical servo moves use this speed. Valid range is 0 to 65535uS/Sec.

LF <arg>, LR <arg>
Set the value for the horizontal servos on the left side of the robot. LF sets the front value, i.e. the pulse width to move the leg to the maximum forward position; LR sets the rear value. The valid range for the arguments is 500 to 2500uS.

RF <arg>, RR <arg>
Set the value for the horizontal servos on the right side of the robot. RF sets the front value, i.e. the pulse width to move the leg to the maximum forward position; RR sets the rear value. The valid range for the arguments is 500 to 2500uS.

HT <arg>
Sets the time to move between horizontal front and rear positions. The valid range for the argument is 1 to 65535uS.

XL <arg>, XR <arg>
Set the travel percentage for left and right legs. The valid range is -100% to 100%. Negative values cause the legs on the side to move in reverse. With a value of 100%, the legs will move between the front and rear positions. Lower values cause the travel to be proportionally less, but always centered. The speed for horizontal moves is adjusted based on the XL and XR commands, so the move time remains the same.

XS <arg>
Set the horizontal speed percentage for all legs. The valid range is 0% to 200%. With a value of 100%, the horizontal travel time will be the value programmed using the HT command. Higher values proportionally reduce the travel time; lower values increase it. A value of 0 will stop the robot in place. The hex sequencer will not be started until the XS command is received.

XSTOP
Stop the hex sequencer. Return all servos to normal operation.

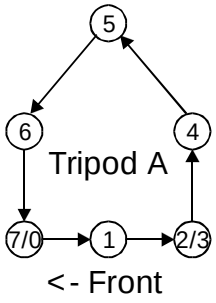
Notes on Hex Sequencer:

1) The following servo channels are used for the Hex Sequencer

0 = Right Rear Vertical	16 = Left Rear Vertical
1 = Right Rear Horizontal	17 = Left Rear Horizontal
2 = Right Center Vertical	18 = Left Center Vertical
3 = Right Center Horizontal	19 = Left Center Horizontal
4 = Right Front Vertical	20 = Left Front Vertical
5 = Right Front Horizontal	21 = Left Front Horizontal

2) The Hexapod walking gait is an alternating tripod. The tripods are labeled Tripod A and Tripod B. Tripod A consists of {Left Front, Left Rear, Right Center}, and Tripod B consists of {Left Center, Right Front, Right Rear}.
3) While walking, the legs pass through 6 points: (Low Front), (Low Center), (Low Rear), (Mid Rear), (High Center), and (Mid Front). "Center" refers to the mid-point between the Front and Rear pulse widths.
4) The walking sequence consists of 8 states, numbered 0 – 7. They are defined below:

State	Tripod A		Tripod B	
	Vertical	**Horizontal**	**Vertical**	**Horizontal**
0	Low	Front to Center	Mid to High	Rear to Center
1	Low	Center to Rear	High to Mid	Center to Front
2	Low	Rear	Mid to Low	Front
3	Low to Mid	Rear	Low	Front
4	Mid to High	Rear to Center	Low	Front to Center
5	High to Mid	Center to Front	Low	Center to Rear
6	Mid to Low	Front	Low	Rear
7	Low	Front	Low to Mid	Rear



In this table, "Front" and "Rear" are modified by the XL and XR commands. A value of 100% results in the movement in the table. Between 0 and 100%, the Front/Rear positions are moved closer to Center. For negative values, Front and Rear are exchanged. For example, with an XL of -100%, in State 0, Tripod A on the left side would be moving Rear to Center, and Tripod B would be moving Front to Center.

5) When a horizontal servo is moving, its speed will be adjusted based on the Front/Rear pulse widths, the XL/XR percentage, and the XS percentage. Regardless of the travel distance from front to rear (adjusted by XL/XR), the total move time will be the HT divided by the XS percentage.
6) When a vertical servo is moving from Low to Mid or from Mid to Low, it will move at the speed specified by the VS command. When a vertical servo is moving from Mid to High or High to Mid, the vertical speed will be adjusted so that the horizontal and vertical movements end at the same time.
7) Any of the Hex Sequencer commands can be issued while the sequencer is operating. They will take effect immediately.

Hex Sequencer Examples:

"LH1000 LM1400 LL1800 RH2000 RM1600 RL1200 VS3000 <cr> "
Sets the vertical servo parameters.

"LF1700 LR1300 RF1300 RR1700 HT1500 <cr> "
Sets the horizontal servo parameters.

"XL50 XR100 XS100 <cr> "
Causes the gradual left turn at 100% speed (and starts the sequencer if it is not already started).

"XL -100 XR 100 XS 50 <cr> "
Causes a left rotate in place at 50% speed.

"XSTOP <cr> "
Stops the sequencer and allows servo channels 0-5, 16-21 to be controlled using the normal servo movement commands.

Query Hex Sequencer State:
XQ <vr>
Returns 1 digit representing the state of the hex sequencer, and the approximate percentage of movement in the state. The high nibble will be '0' to '7', and the low nibble will be '0' to '9'. For example, if the sequencer is 80% of the way through state 5, it will return the value 58 hex.

Get Software Version:
VER <cr>
Returns the software version number as an ASCII string.

Transfer to Boot:
GOBOOT <cr>
Starts the bootloader running for software updates. To exit the bootloader and start running the application, power cycle the control or enter (case sensitive, no spaces).

g0000<cr>

SSC Emulation: Binary format, 3-bytes.
Byte 1: 255, the sync byte
Byte 2: 0 - 31, the servo number
Byte 3: 0 - 250, the pulse width, 0=500uS, 125=1500uS, 250=2500uS

Testing the Controller

The easiest way to test the controller is to use the Lynx SSC-32 Terminal. It's a free download from the website. Once installed click on the Port Drop Down and select your com port. This will work with USB to serial port adaptors. Install the jumpers for 115.2k baud and the two DB9 serial port enable jumpers. Plug a straight through DB9 M/F cable from the PC to the controller.

Install two servos, one on channel 0 and one on channel 1.

Power up the SSC-32 (Logic and Servo) and notice the green LED is illuminated.

Then click on the terminal window so you can type the following into it.

#0 P1500 #1 P1500 <cr> <- (This means hit Enter.)

You should notice both servos are holding position in the center of their range. The LED is also no longer illuminated. It will now only light when the controller is receiving data. Type the following:

#0 P750 #1 P1000 T3000 <cr>

You should notice servo 0 moving CW slowly and servo 1 moving CCW a bit faster. They will arrive at their destination at the exact same time even though they are moving different distances.

Now to test the Query Movement Status. Type the following:

#0 P750 <cr>

Then type the following line. This will make the servo move full range in 10 seconds.

#0 P2250 T10000 <cr>

While the servo is moving type the following:

Q <cr>

When the servo is in motion the controller will return a "+". It will return a "." when it has reached its destination.

To experiment with the speed argument try the following:

#0 P750 S1000 <cr>

This will move the servo from 2250 to 750 (around 170°) in 1.5 seconds.

$$\frac{\text{2250uS-750uS (travel distance)}}{\text{1000uS/Sec. (speed value)}} = 1.5 \text{ Sec.}$$

Next try typing the following:

#0 P2250 S750 <cr>

This will move the servo from 750 to 2250 (around 170°) in 2.0 seconds.

$$\frac{\text{2250uS-750uS (travel distance)}}{\text{750uS/Sec. (speed value)}} = 2.0 \text{ Sec.}$$

Speed values above around 3500 will move the servo as quickly as the servo can move.

Updating the SSC-32 firmware
From the SSC-32 Terminal main screen click on Firmware. This will show the current version of the firmware at the top, and allow you to browse and open the new *.abl firmware file. Click Begin Update to finish the update process.

Don't forget to check the website for the latest tutorials for the servo controller.

Troubleshooting Information
If you notice the servos turn off, or stop holding position when moving several servos at one time. This indicates the SSC-32 has reset. This can be verified by noticing if the green LED is on steady after the servos are instructed to move. The green LED is not a power indicator, but a status indicator. When the SSC-32 is turned on the LED will be on steady. It will remain on until it has received a valid serial command, then it will go out and only blink when receiving serial data.

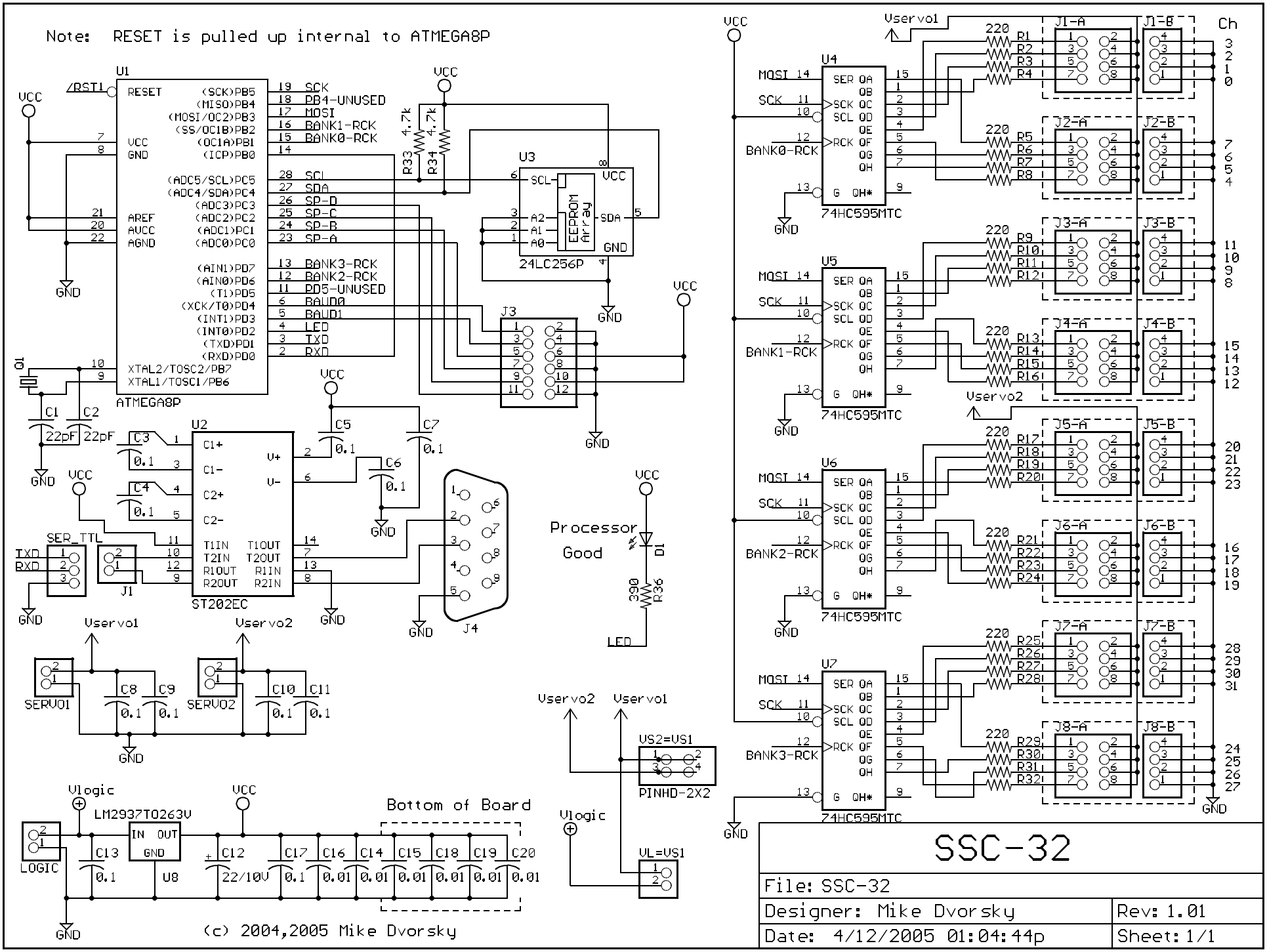
The SSC-32 has two power supply inputs. The logic supply (VL) powers the microcontroller and it's support circuitry through a 5vdc regulator. The servo supply (VS) powers the servos directly. In single supply mode (default) the jumper VS1=VL will provide power to the VL 5vdc regulator from the VS terminal. This works great for battery use, and with most wall pack use, as long as the voltage does not drop too much. However if it does drop, the voltage to the microcontroller is interrupted and the SSC-32 resets. To fix this you remove the VS1=VL jumper and connect a 9vdc battery clip to the VL input. This isolates the servo and logic supplies so one cannot effect the other.

Using the single supply mode is generally safe for the following conditions:
- VS of 7.2vdc 2800mAh NiCad or NiMH battery packs for up to 24 servos.
- VS of 7.4vdc 2800mAh LiPo battery packs for up to 24 servos.
- VS of 6.0vdc 1600mAh NiCad or NiMH battery packs for up to 18 servos.
- VS of 6.0vdc 2.0amp wall pack for up to 8 servos.

Note, these are just general guidelines and some exceptions may exist. The only other thing that can cause this effect is a poor power delivery system. If the wires carrying the current are too small, or connections are made with stripped and twisted wire, or cheap plastic battery holders are used, the same problem may occur. 99% of customers problems with the SSC-32 are power supply related. If you are noticing erratic or unstable servo movements, look at the power delivery system.

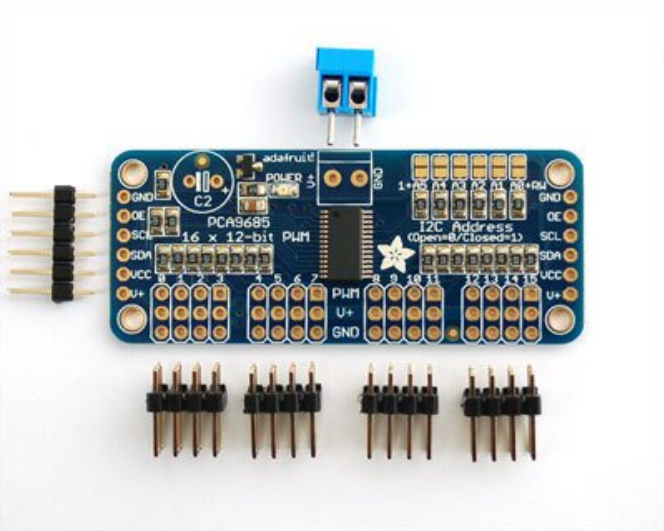
Basic Atom Programming Examples for the SSC-32

```
' Atom / SSC-32 Test
' Configure the SSC-32 for 38.4k baud.

servo0pw  var  word
movetime  var  word

servo0pw = 1000
movetime = 2500

start:
servo0pw = 1000
serout p0,i38400,["#0P",DEC servo0pw,"T",DEC movetime,13]
pause 2500
servo0pw = 2000
serout p0,i38400,["#0P",DEC servo0pw,"T",DEC movetime,13]
pause 2500
goto start

' Biped example program.
aa  var  byte   '<- general purpose variable.
rax  var  word  '<- right ankle side-to-side.   On pin0
ray  var  word  '<- right ankle front-to-back.  On pin1
rkn  var  word  '<- right knee.                 On pin2
rhx  var  word  '<- right hip front-to-back.    On pin3
rhy  var  word  '<- right  hip side-to-side.    On pin4
lax  var  word  '<- left ankle side-to-side.    On pin5
lay  var  word  '<- left ankle front-to-back.   On pin6
lkn  var  word  '<- left knee.                  On pin7
lhx  var  word  '<- left hip front-to-back.     On pin8
lhy  var  word  '<- left hip side-to-side.      On pin9
ttm  var  word  '<- time to take for the current move.

' First command to turn the servos on.
for aa=0 to 9
serout p0,i38400,["#", DEC2 aa\1, "P", DEC 1500, 13]
next

start:
' First position for step sequence, and time to move, put in your values here.
rax=1400: ray=1400: rkn=1400: rhx=1400: rhy=1400
lax=1400: lay=1400: lkn=1400: lhx=1400: lhy=140 0
ttm=1000
gosub send_data
pause ttm

' Second position for step sequence, and time to move, put in your values here.
rax=1600: ray=1600: rkn=1600: rhx=1600: rhy=1600
lax=1600: lay=1600: lkn=1600: lhx=1600: lhy=1600
ttm=1000
gosub send_data
pause ttm

' Third...

' Forth...

' Etc...

goto start

' This sends the data to the SSC-32. The serout is all one line, no Wrap!
send_data:
serout p0,i38400,["#0P",DEC rax,"#1P",DEC ray,"#2P",DEC rkn,"#3P",DEC rhx,"#4P",DEC
rhy,"#5P",DEC lax,"#6P",DEC lay,"#7P",DEC lkn,"#8P",DEC lhx,"#9P",DEC lhy,"T",DEC
ttm,13]
return
```


Note: RESET is pulled up internal to ATMEGA8P
U1
ATMEGA8P
/RST1
RESET
VCC
GND
AREF
AVCC
AGND
XTAL2/TOSC2/PB7
XTAL1/TOSC1/PB6
(SCK)PB5
(MISO)PB4
(MOSI/OC2)PB3
(SS/OC1B)PB2
(OC1A)PB1
(ICP)PB0
(ADC5/SCL)PC5
(ADC4/SDA)PC4
(ADC3)PC3
(ADC2)PC2
(ADC1)PC1
(ADC0)PC0
(AIN1)PD7
(AIN0)PD6
(T1)PD5
(XCK/T0)PD4
(INT1)PD3
(INT0)PD2
(TXD)PD1
(RXD)PD0
SCK
PB4-UNUSED
MOSI
BANK1-RCK
BANK0-RCK
SCL
SDA
SP-D
SP-C
SP-B
SP-A
BANK3-RCK
BANK2-RCK
PD5-UNUSED
BAUD0
BAUD1
LED
TXD
RXD
Q1
C1
C2
22pF
U2
ST202EC
C1+
C1-
C2+
C2-
V+
V-
T1IN
T2IN
R1OUT
R2OUT
T1OUT
T2OUT
R1IN
R2IN
C3
C4
C5
C6
C7
0.1
SER_TTL
J1
J3
J4
U3
24LC256P
EEPROM Array
A2
A1
A0
R33
R34
4.7k
Processor Good
D1
R36
390
LED
Vservo1
Vservo2
SERVO1
SERVO2
C8
C9
C10
C11
Vlogic
LM2937T0263V
IN
OUT
U8
LOGIC
C13
C12
22/10V
C17
C16
C14
C15
C18
C19
C20
0.01
Bottom of Board
VS2=VS1
PINHD-2X2
VL=VS1
(c) 2004,2005 Mike Dvorsky
U4
U5
U6
U7
74HC595MTC
SER
QA
QB
QC
QD
QE
QF
QG
QH
QH*
SCK
RCK
G
MOSI
BANK0-RCK
BANK1-RCK
BANK2-RCK
BANK3-RCK
220
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
R16
R17
R18
R19
R20
R21
R22
R23
R24
R25
R26
R27
R28
R29
R30
R31
R32
J1-A
J1-B
J2-A
J2-B
J3-A
J3-B
J4-A
J4-B
J5-A
J5-B
J6-A
J6-B
J7-A
J7-B
J8-A
J8-B
Ch
SSC-32
File: SSC-32
Designer: Mike Dvorsky
Rev: 1.01
Date: 4/12/2005 01:04:44p
Sheet: 1/1

Adafruit 16-Channel Servo Driver with Arduino

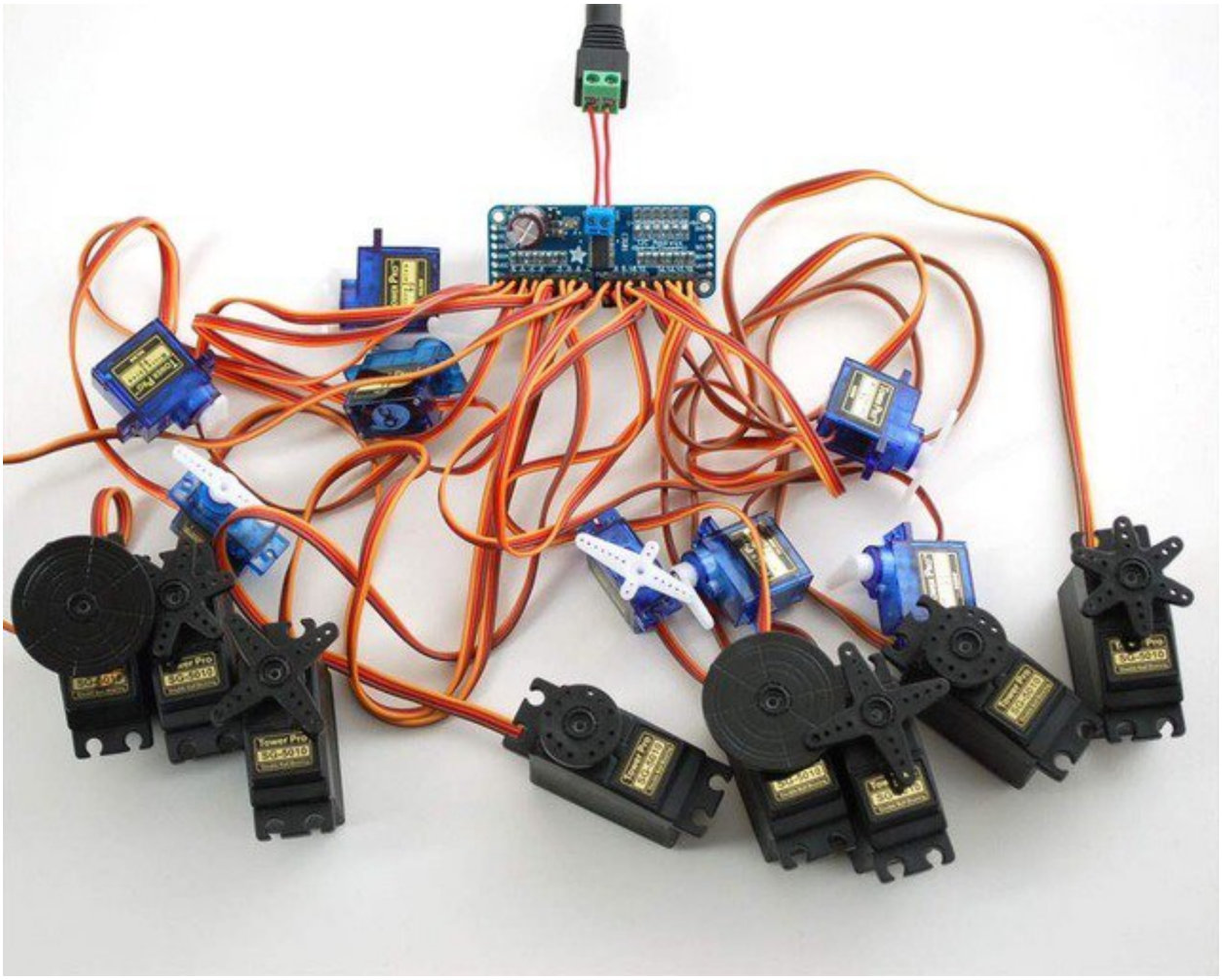
Created by Bill Earl



Last updated on 2016-10-07 04:59:20 PM UTC

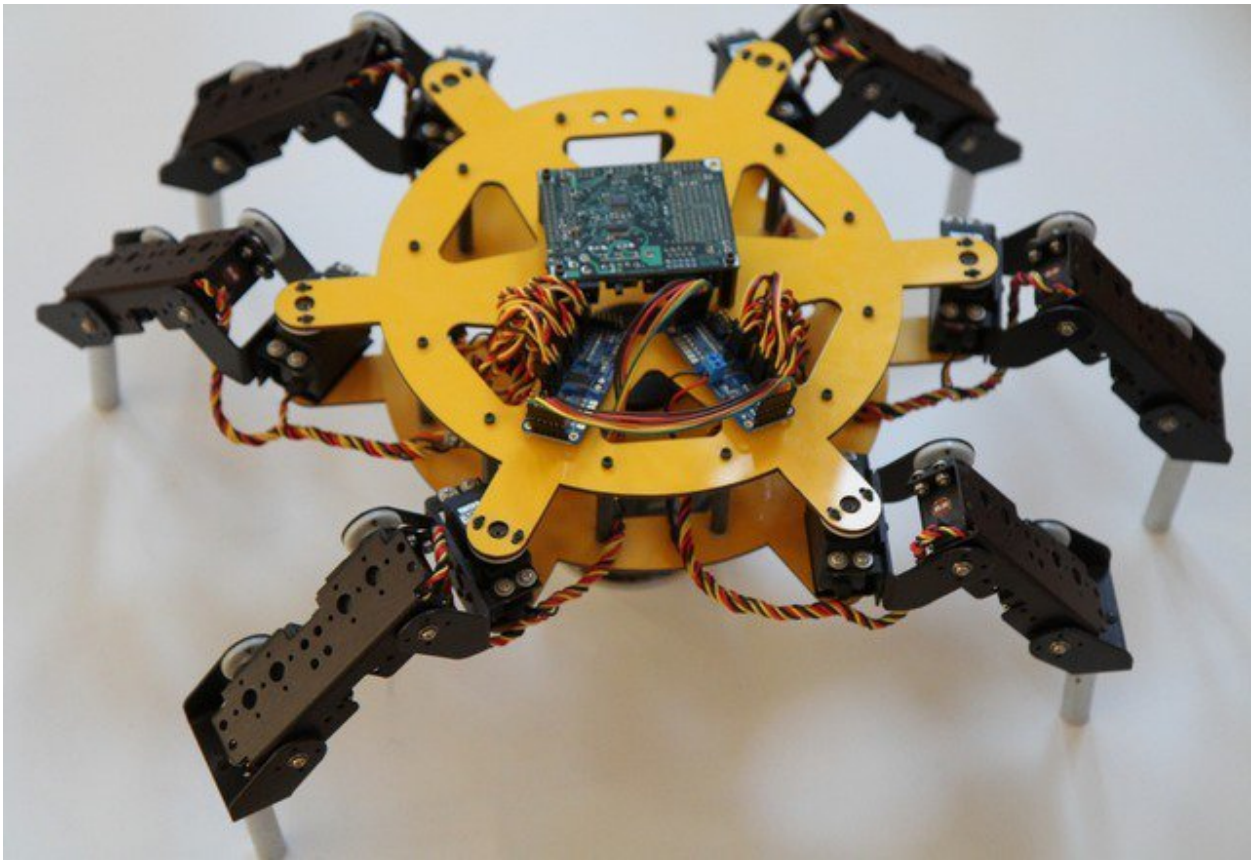
Guide Contents

Overview

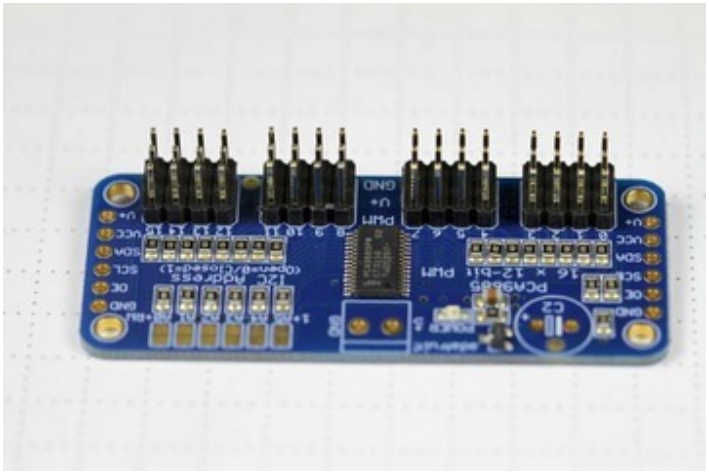


Driving servo motors with the Arduino Servo library is pretty easy, but each one consumes a precious pin - not to mention some Arduino processing power. The Adafruit 16-Channel 12-bit PWM/Servo Driver will drive up to 16 servos over I2C with only 2 pins. The on-board PWM controller will drive all 16 channels simultaneously with no additional Arduino processing overhead. What's more, you can chain up to 62 of them to control up to 992 servos - all with the same 2 pins!

The Adafruit PWM/Servo Driver is the perfect solution for any project that requires a lot of servos.

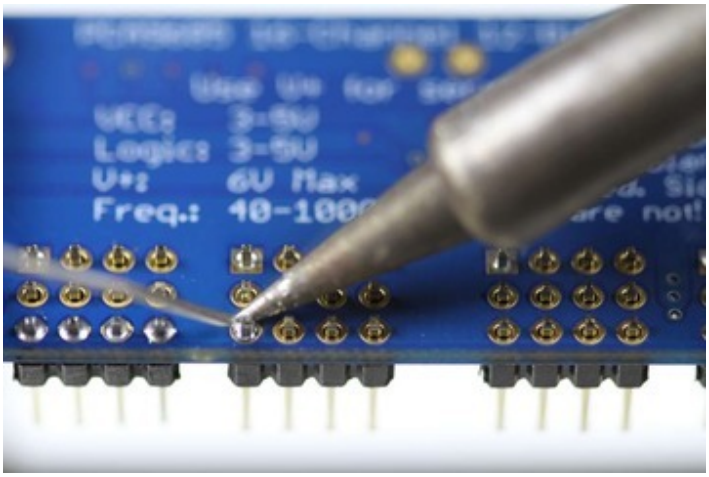


Assembly

- 

Install the Servo Headers

Install 4 3x4 pin male headers into the marked positions along the edge of the board.

- 

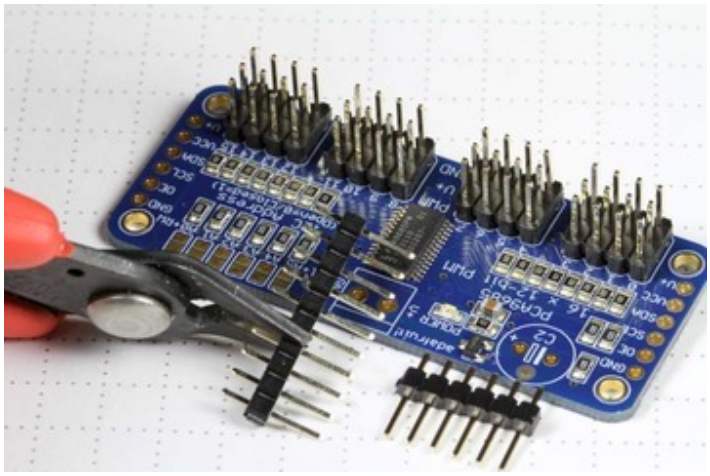
Solder all pins

There are a lot of them!

Add Headers for Control

A strip of male header is included. Where you want to install headers and on what side depends a little on use:

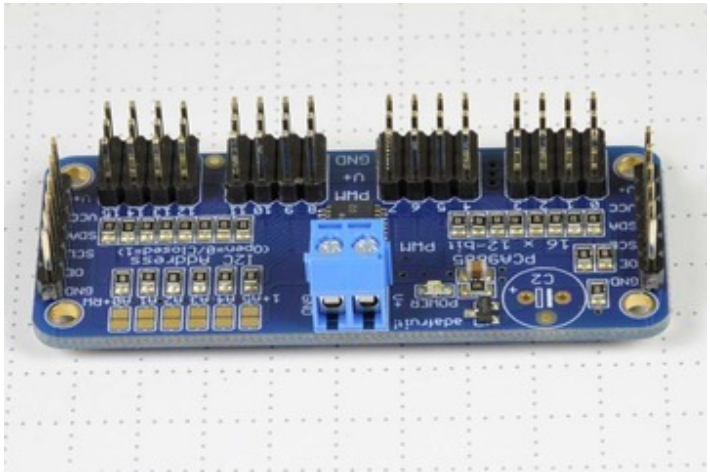
- **For [breadboard](http://adafru.it/239) use**, install headers on the

- 

bottom of the board.

- **For use with [jumper wires](http://adafru.it/758)**, install the headers on top of the board.
- **For use with our [6-pin cable](http://adafru.it/206)**, install the headers on top of the board.

If you are chaining multiple driver boards, you will want headers on both ends.

- 

Install Power Terminals

If you are chaining multiple driver boards, you only need a power terminal on the first one.

Hooking it Up

Connecting to the Arduino

The PWM/Servo Driver uses I2C so it take only 4 wires to connect to your Arduino:

"Classic" Arduino wiring:

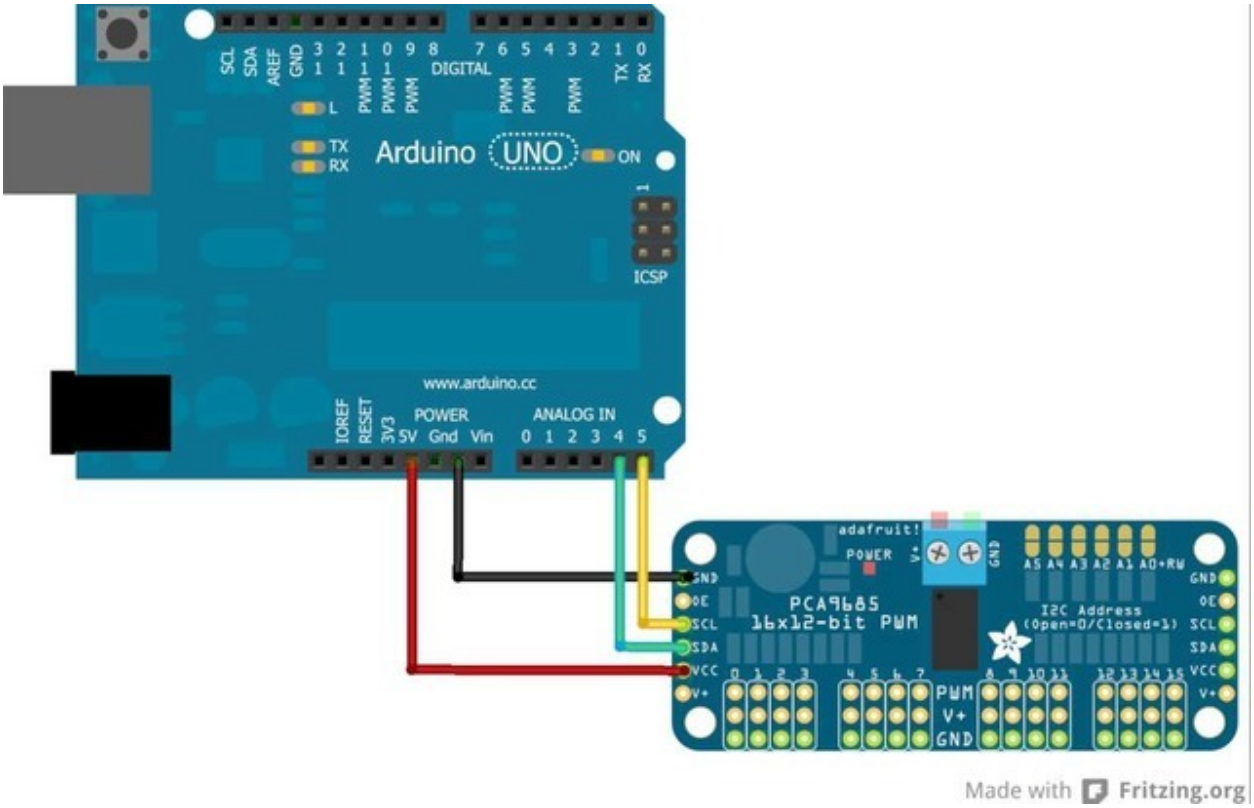
- +5v -> VCC (this is power for the BREAKOUT only, NOT the servo power!)
- GND -> GND
- Analog 4 -> SDA
- Analog 5 -> SCL

Older Mega wiring:

- +5v -> VCC (this is power for the BREAKOUT only, NOT the servo power!)
- GND -> GND
- Digital 20 -> SDA
- Digital 21 -> SCL

R3 and later Arduino wiring (Uno, Mega & Leonardo):
(These boards have dedicated SDA & SCL pins on the header nearest the USB connector)

- +5v -> VCC (this is power for the BREAKOUT only, NOT the servo power!)
- GND -> GND
- SDA -> SDA
- SCL -> SCL



The VCC pin is just power for the chip itself. If you want to connect servos or LEDs that use the V+ pins, you MUST connect the V+ pin as well. The V+ pin can be as high as 6V even if VCC is 3.3V (the chip is 5V safe). We suggest connecting power through the blue terminal block since it is polarity protected.

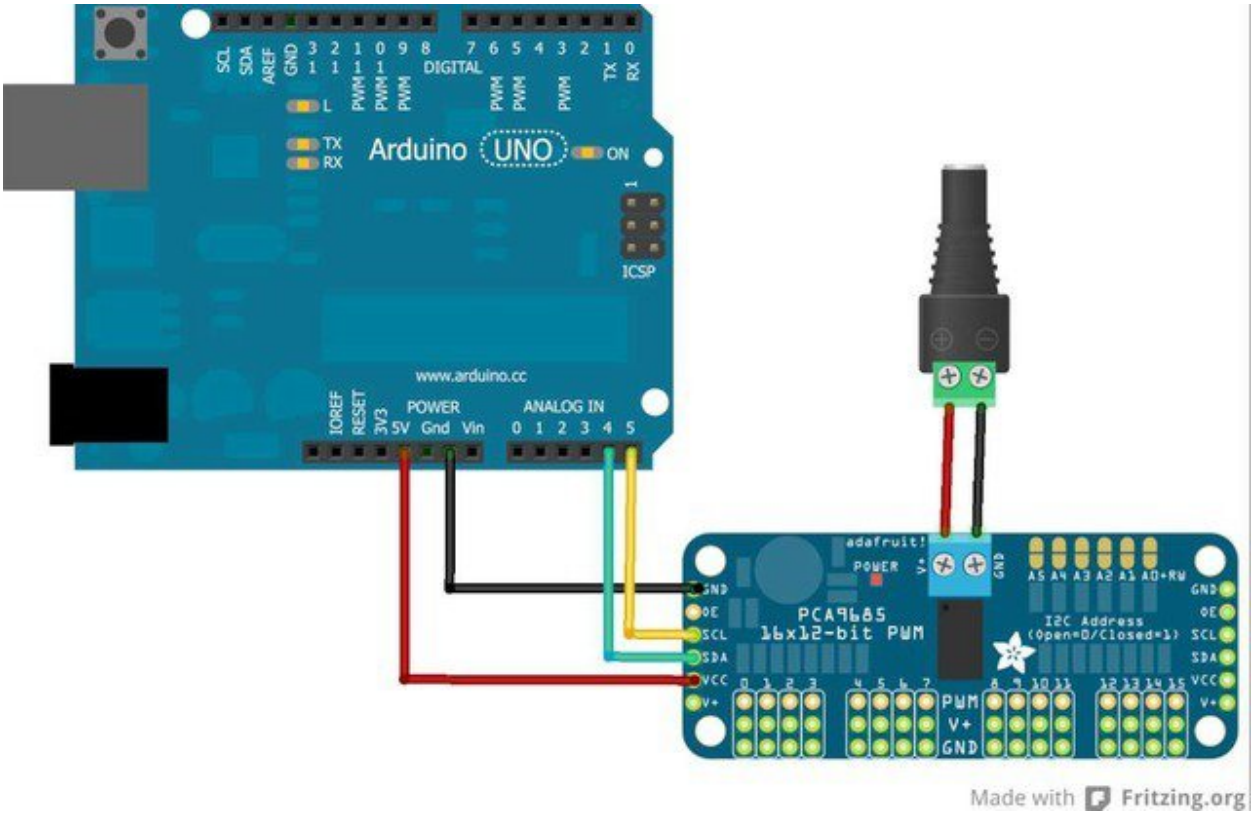
Power for the Servos

Most servos are designed to run on about 5 or 6v. Keep in mind that a lot of servos moving at the same time (particularly large powerful ones) will need a lot of current. Even micro servos will draw several hundred mA when moving. Some High-torque servos will draw more than 1A each under load.

Good power choices are:

- 5v 2A switching power supply (http://adafru.it/276)
- 5v 10A switching power supply (http://adafru.it/658)
- 4xAA Battery Holder (http://adafru.it/830) - 6v with Alkaline cells. 4.8v with NiMH rechargeable cells.
- 4.8 or 6v Rechargeable RC battery packs from a hobby store.

It is not a good idea to use the Arduino 5v pin to power your servos. Electrical noise and 'brownouts' from excess current draw can cause your Arduino to act erratically, reset and/or overheat.

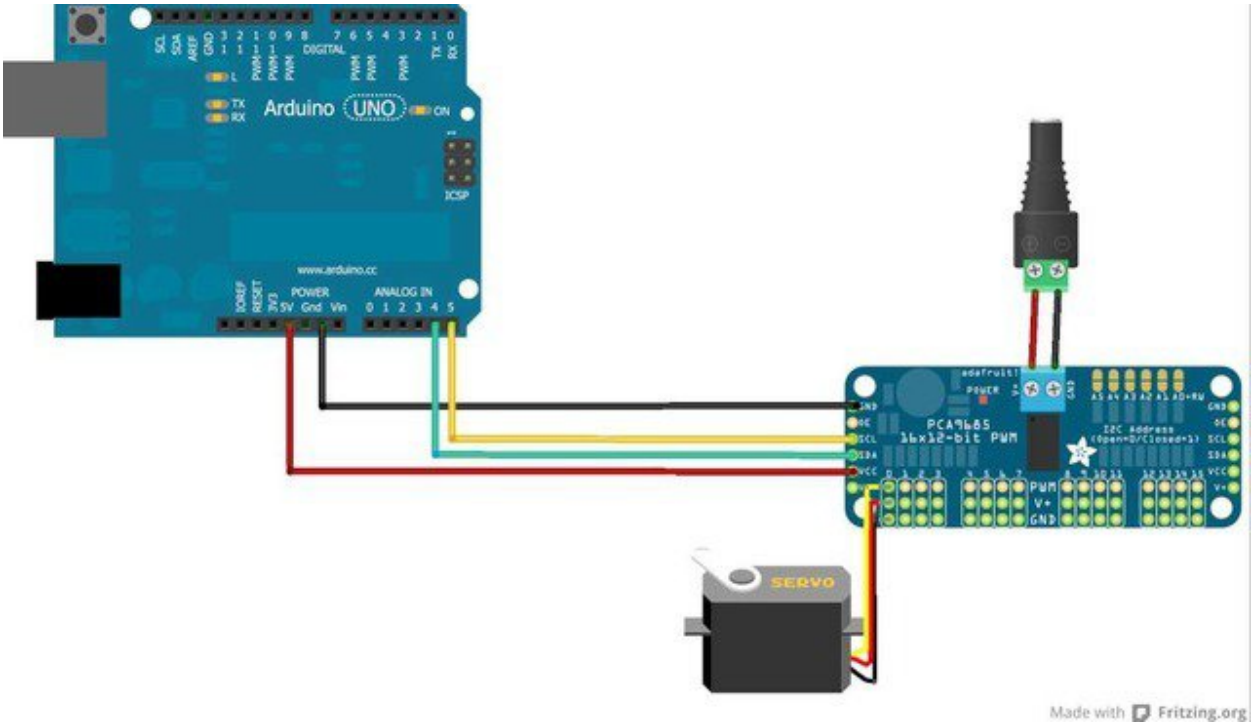


Adding a Capacitor to the thru-hole capacitor slot

We have a spot on the PCB for soldering in an electrolytic capacitor. Based on your usage, you may or may not need a capacitor. If you are driving a lot of servos from a power supply that dips a lot when the servos move, **n * 100uF** where **n** is the number of servos is a good place to start - eg **470uF** or more for 5 servos. Since its so dependent on servo current draw, the torque on each motor, and what power supply, there is no "one magic capacitor value" we can suggest which is why we don't include a capacitor in the kit.

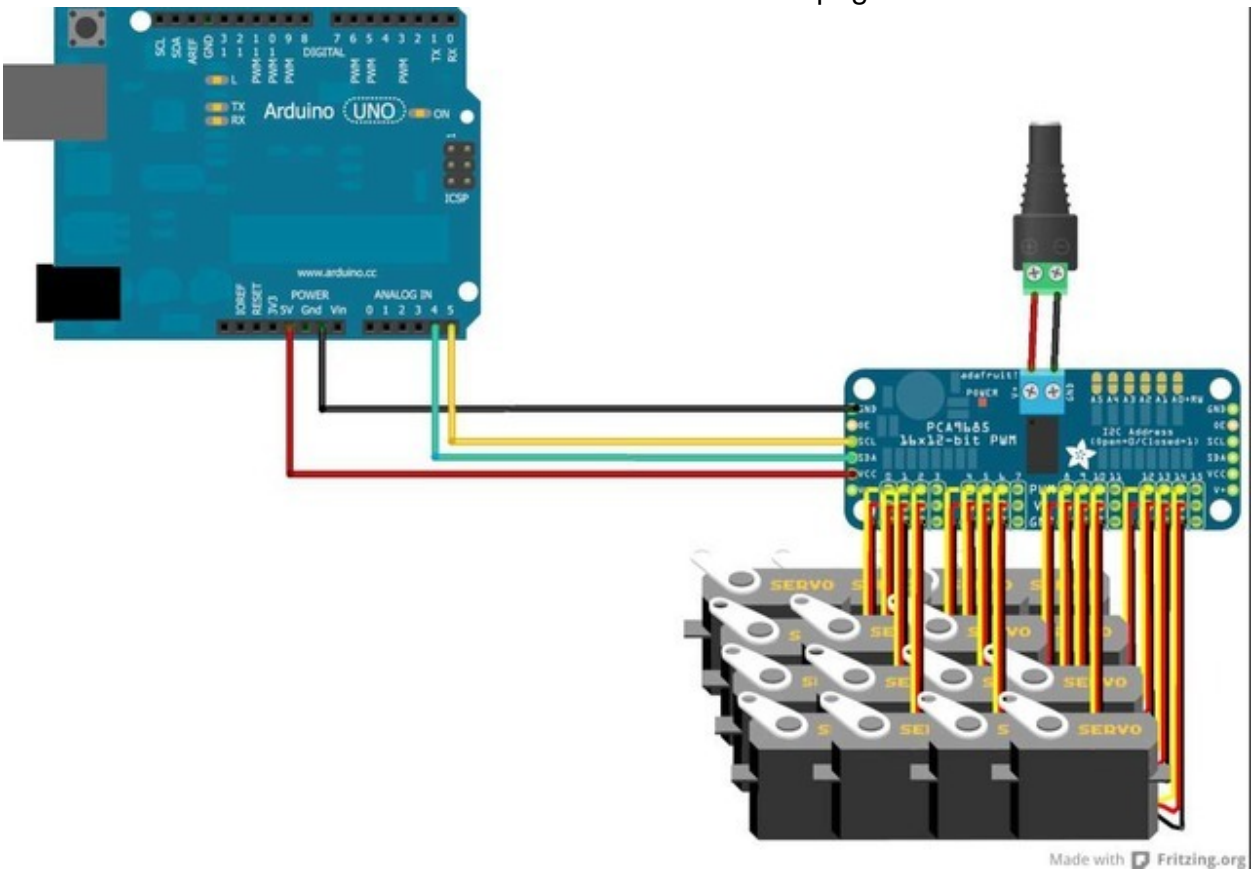
Connecting a Servo

Most servos come with a standard 3-pin female connector that will plug directly into the headers on the Servo Driver. Be sure to align the plug with the ground wire (usually black or brown) with the bottom row and the signal wire (usually yellow or white) on the top.



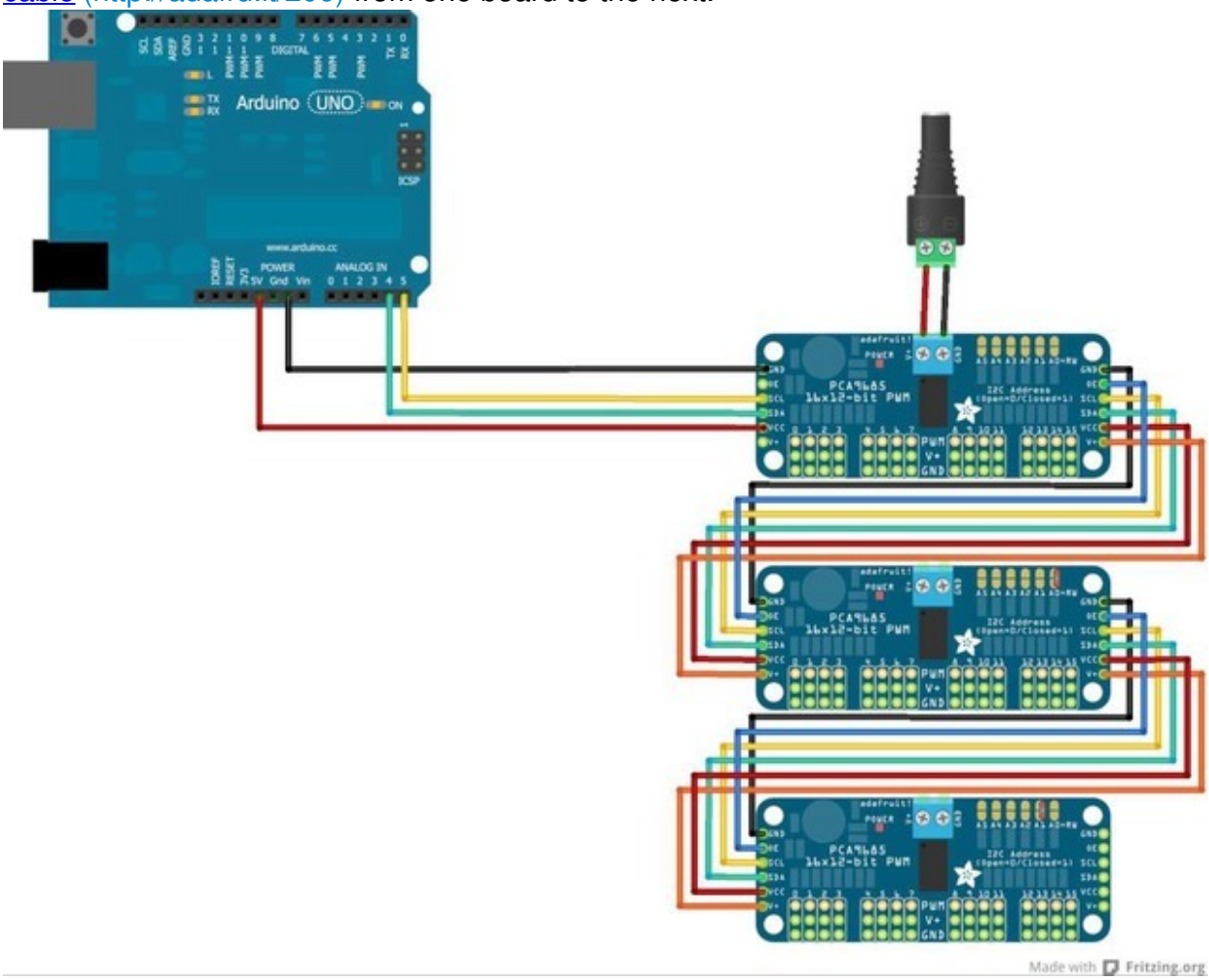
Adding More Servos

Up to 16 servos can be attached to one board. If you need to control more than 16 servos, additional boards can be chained as described on the next page.



Chaining Drivers

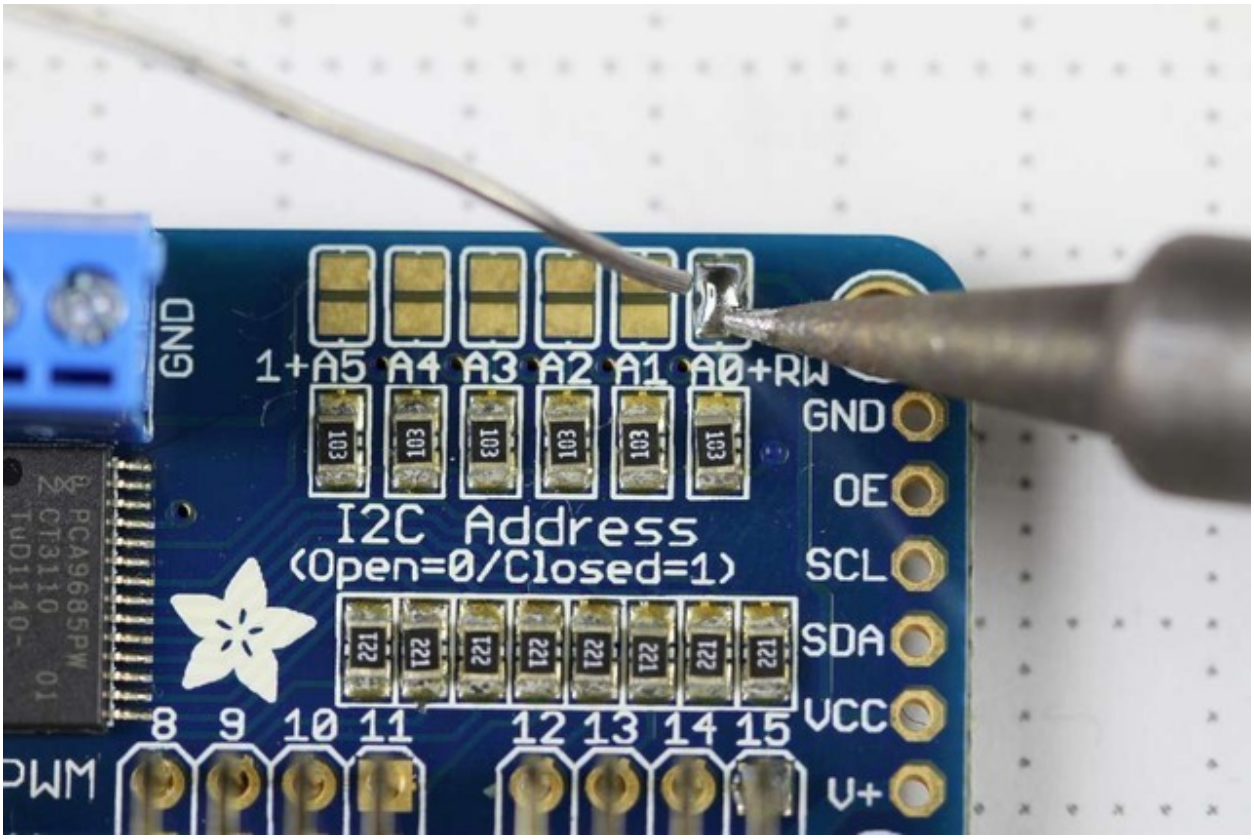
Multiple Drivers (up to 62) can be chained to control still more servos. With headers at both ends of the board, the wiring is as simple as connecting a [6-pin parallel cable (http://adafru.it/206)](http://adafru.it/206) from one board to the next.



Addressing the Boards

Each board in the chain must be assigned a unique address. This is done with the address jumpers on the upper right edge of the board. The I2C base address for each board is 0x40. The binary address that you program with the address jumpers is added to the base I2C address.

To program the address offset, use a drop of solder to bridge the corresponding address jumper for each binary '1' in the address.



Board 0: Address = 0x40 Offset = binary 00000 (no jumpers required)
Board 1: Address = 0x41 Offset = binary 00001 (bridge A0 as in the photo above)
Board 2: Address = 0x42 Offset = binary 00010 (bridge A1)
Board 3: Address = 0x43 Offset = binary 00011 (bridge A0 & A1)
Board 4: Address = 0x44 Offset = binary 00100 (bridge A2)

etc.

In your sketch, you'll need to declare a separate pobject for each board. Call begin on each object, and control each servo through the object it's attached to. For example:

```
#include <Wire.h>
#include <Adafruit_PWMServoDriver.h>

Adafruit_PWMServoDriver pwm1 = Adafruit_PWMServoDriver(0x40);
Adafruit_PWMServoDriver pwm2 = Adafruit_PWMServoDriver(0x41);

void setup() {
  Serial.begin(9600);
  Serial.println("16 channel PWM test!");

  pwm1.begin();
  pwm1.setPWMFreq(1600);  // This is the maximum PWM frequency

  pwm2.begin();
  pwm2.setPWMFreq(1600);  // This is the maximum PWM frequency
```

```
}
```

Using the Adafruit Library

Since the PWM Servo Driver is controlled over I2C, its super easy to use with any microcontroller or microcomputer. In this demo we'll show using it with the Arduino IDE but the C++ code can be ported easily

Download the library from Github

Start by downloading the library from the GitHub repository (http://adafru.it/aQl) You can do that by visiting the github repo and manually downloading or, easier, just click this button to download the zip

Download Adafruit PWM/Servo Library
http://adafru.it/cDw

Rename the uncompressed folder **Adafruit_PWMServoDriver** and check that the **Adafruit_PWMServoDriver** folder contains **Adafruit_PWMServoDriver.cpp** and **Adafruit_PWMServoDriver.h**

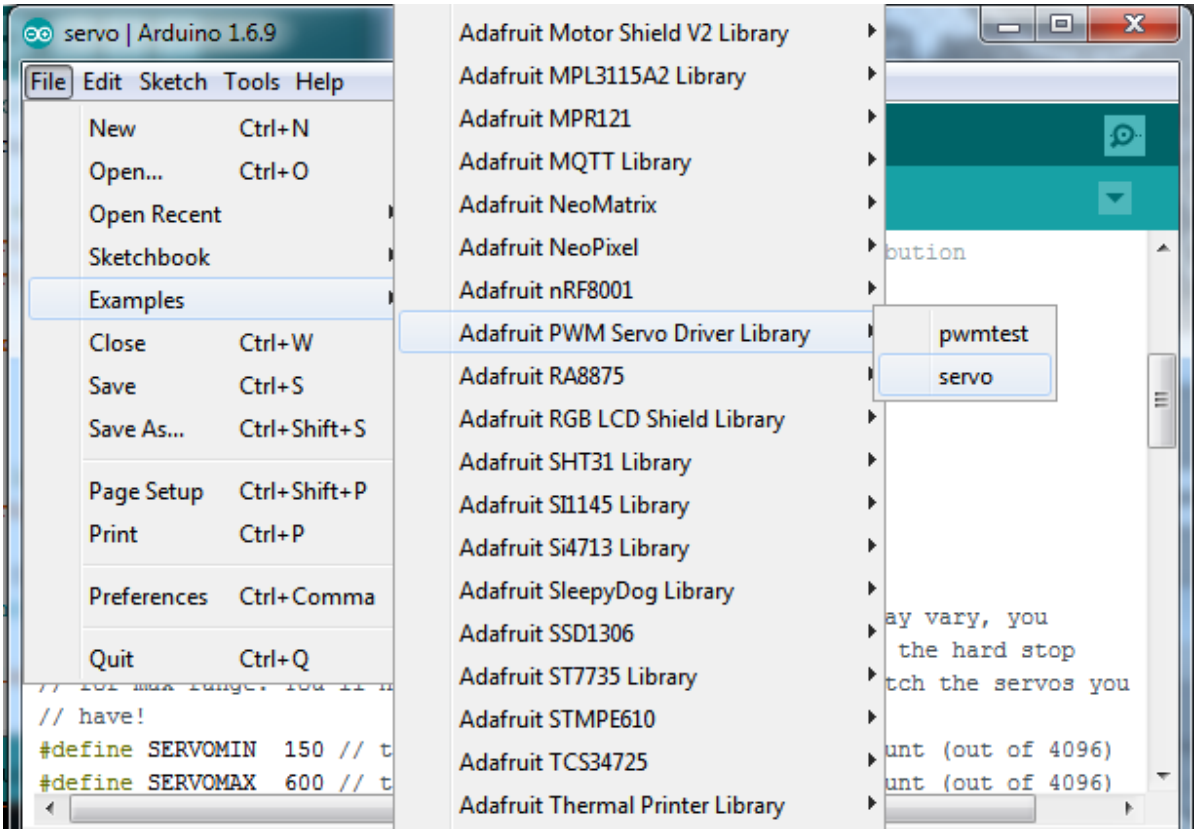
Place the **Adafruit_PWMServoDriver** library folder your **arduinosketchfolder/libraries/** folder. You may need to create the**libraries** subfolder if its your first library. Restart the IDE.

We also have a great tutorial on Arduino library installation at:
http://learn.adafruit.com/adafruit-all-about-arduino-libraries-install-use (http://adafru.it/aYM)

Test with the Example Code:

First make sure all copies of the Arduino IDE are closed.

Next open the Arduino IDE and select **File->Examples->Adafruit_PWMServoDriver->Servo**. This will open the example file in an IDE window.



If using a Breakout:

Connect the driver board and servo as shown on the previous page. Don't forget to provide power to both **Vin** (3-5V logic level) and **V+** (5V servo power). **Check the green LED is lit!**

If using a Shield:

Plug the shield into your Arduino. Don't forget you will also have to provide 5V to the V+ terminal block. **Both red and green LEDs must be lit**

If using a FeatherWing:

Plug the FeatherWing into your Feather. Don't forget you will also have to provide 5V to the V+ terminal block. **Check the green LED is lit!**

Connect a Servo

A single servo should be plugged into the **PWM #0** port, the first port. You should see the servo sweep back and forth over approximately 180 degrees.

Calibrating your Servos

Servo pulse timing varies between different brands and models. Since it is an analog control circuit, there is often some variation between samples of the same brand and model. For precise position control, you will want to calibrate the minumum and maximum pulse-widths in your code to match known positions of the servo.

Find the MInimum:
Using the example code, edit SERVOMIN until the low-point of the sweep reaches the minimum range of travel. It is best to approach this gradually and stop before the physical limit of travel is reached.

Find the Maximum:
Again using the example code, edit SERVOMAX until the high-point of the sweep reaches the maximum range of travel. Again, is best to approach this gradually and stop before the physical limit of travel is reached.
Use caution when adjusting SERVOMIN and SERVOMAX. Hitting the physical limits of travel can strip the gears and permanently damage your servo.

Converting from Degrees to Pulse Length

The Arduino "map()" function (http://adafru.it/aQm) is an easy way to convert between degrees of rotation and your calibrated SERVOMIN and SERVOMAX pulse lengths. Assuming a typical servo with 180 degrees of rotation; once you have calibrated SERVOMIN to the 0-degree position and SERVOMAX to the 180 degree position, you can convert any angle between 0 and 180 degrees to the corresponding pulse length with the following line of code:

```
pulselength = map(degrees, 0, 180, SERVOMIN, SERVOMAX);
```

Library Reference

setPWMFreq(freq)

Description

This function can be used to adjust the PWM frequency, which determines how many full 'pulses' per second are generated by the IC. Stated differently, the frequency determines how 'long' each pulse is in duration from start to finish, taking into account both the high and low segments of the pulse.

Frequency is important in PWM, since setting the frequency too high with a very small duty cycle can cause problems, since the 'rise time' of the signal (the time it takes to go from 0V to VCC) may be longer than the time the signal is active, and the PWM output will appear smoothed out and may not even reach VCC, potentially causing a number of problems.

Arguments

- **freq**: A number representing the frequency in Hz, between 40 and 1000

Example

The following code will set the PWM frequency to the maximum value of 1000Hz:

```
pwm.setPWMFreq(1000)
```

setPWM(channel, on, off)

Description

This function sets the start (on) and end (off) of the high segment of the PWM pulse on a specific channel. You specify the 'tick' value between 0..4095 when the signal will turn on, and when it will turn of. Channel indicates which of the 16 PWM outputs should be updated with the new values.

Arguments

- **channel**: The channel that should be updated with the new values (0..15)
- **on**: The tick (between 0..4095) when the signal should transition from low to high
- **off**:the tick (between 0..4095) when the signal should transition from high to low

Example

The following example will cause channel 15 to start low, go high around 25% into the pulse (tick 1024 out of 4096), transition back to low 75% into the pulse (tick 3072), and remain low for the last 25% of the pulse:

```
pwm.setPWM(15, 1024, 3072)
```

FAQ

Can this board be used for LEDs or just servos?
It can be used for LEDs as well as any other PWM-able device!
I am having strange problems when combining this shield with the Adafruit LED Matrix/7Seg Backpacks
We are not sure why this occurs but there is an address collision even though the address are different! Set the backpacks to address 0x71 or anything other than the default 0x70 to make the issue go away.
With LEDs, how come I cant get the LEDs to turn completely off?
If you want to turn the LEDs totally off use **setPWM(pin, 4096, 0);** not **setPWM(pin, 4095, 0);**
I can't get this to work with my 7-segment LED display.

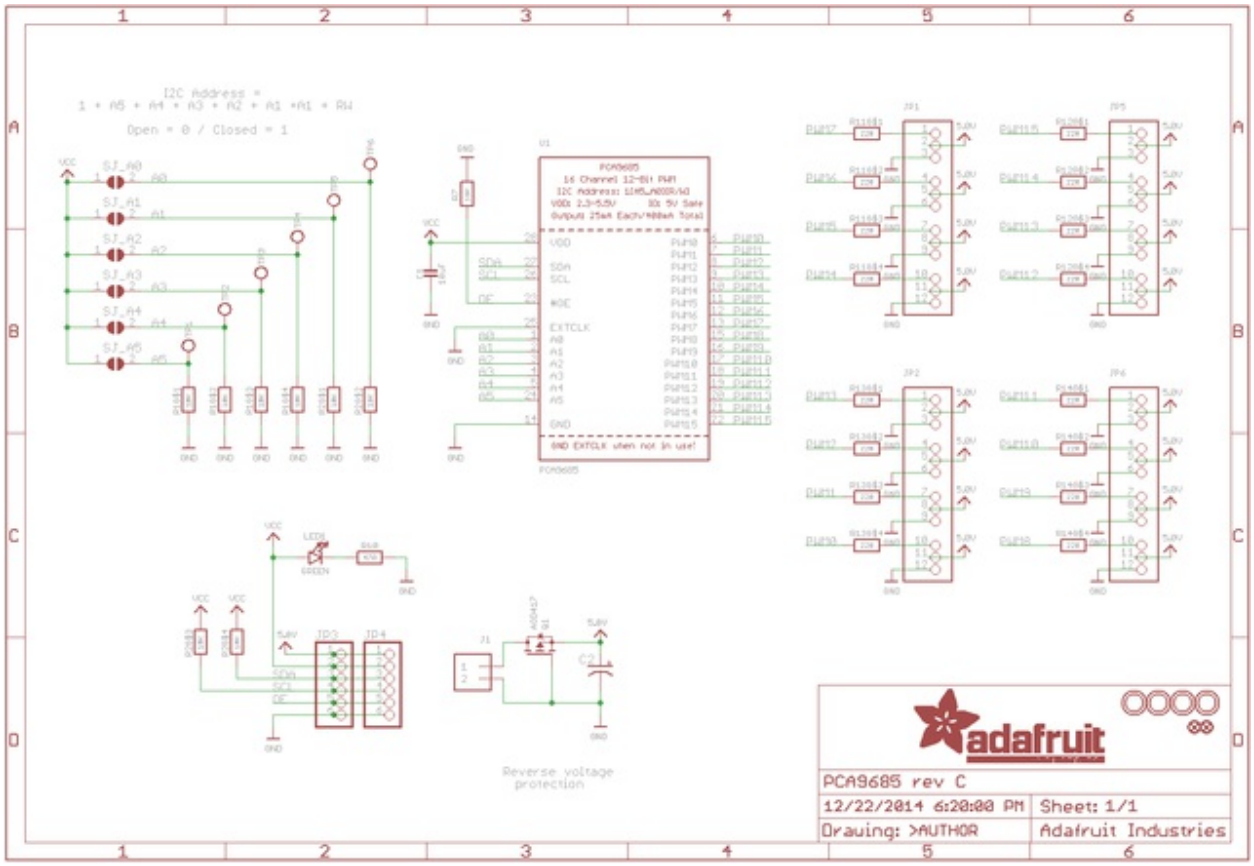
The PCA9865 chip has an "All Call" address of 0x70. This is in addition to the configured address. This will cause an address collision if used with any other chip addressed to 0x70.

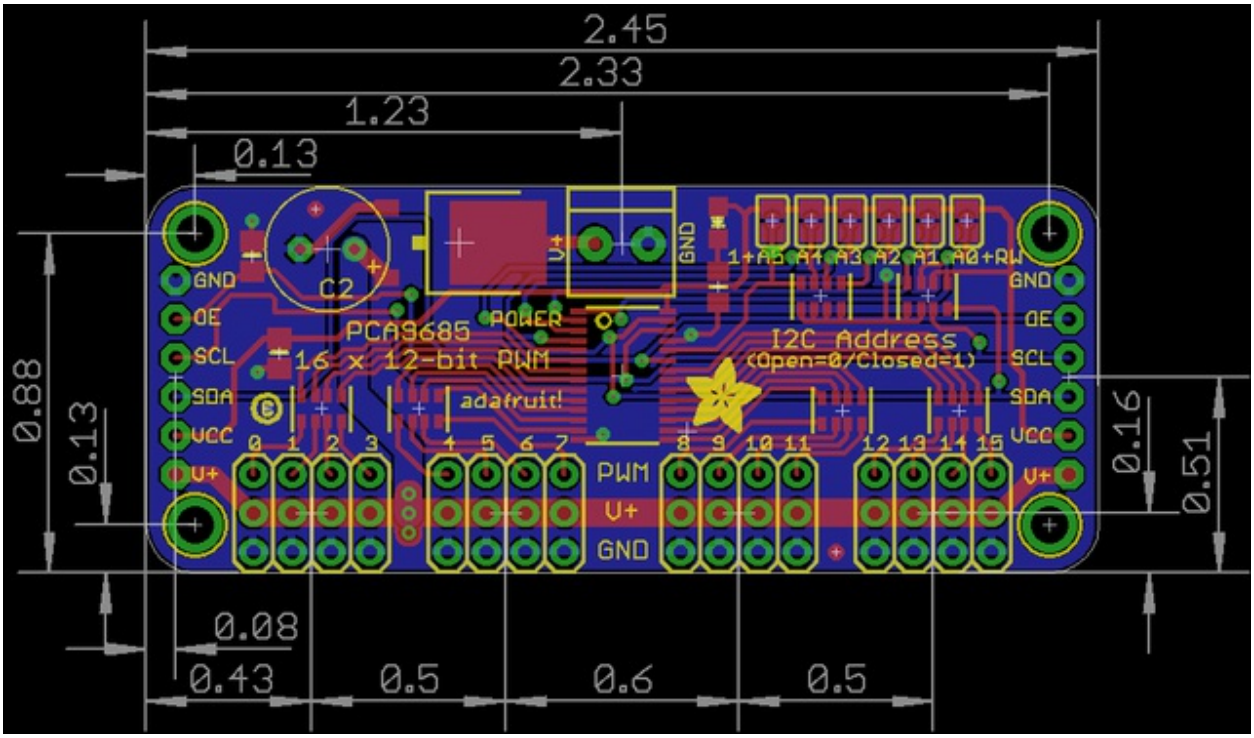
Downloads

Files

- PCA9685 datasheet (http://adafru.it/okB)
- Arduino driver library (http://adafru.it/aQl)
- EagleCAD PCB files on GitHub (http://adafru.it/rME)
- Fritzing object in the Adafruit Fritzing library (http://adafru.it/aP3)

Schematic & Fabrication Print



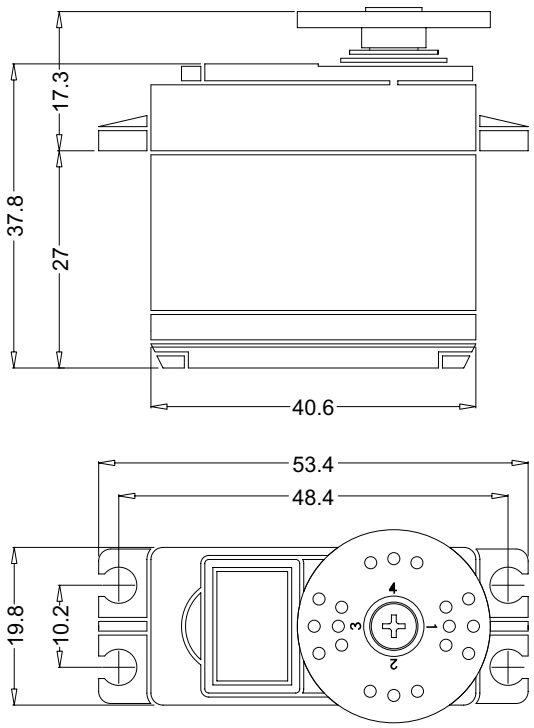

2.45
2.33
1.23
0.13
0.88
0.13
0.16
0.51
0.08
0.43
0.5
0.6
0.5
GND
OE
SCL
SDA
VCC
V+
C2
PCA9685
16 x 12-bit PWM
POWER
V+
GND
1+A5 A4 A3 A2 A1 A0+RW
I2C Address
(Open=0/Closed=1)
adafruit
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
PWM
V+
GND

°

ANNOUNCED SPECIFICATION OF HS-645MG STANDARD DELUXE HIGH TORQUE SERVO

1.TECHNICAL VALUES

CONTROL SYSTEM	:+PULSE WIDTH CONTROL 1500usec NEUTRAL	
OPERATING VOLTAGE RANGE	:4.8V TO 6.0V	
OPERATING TEMPERATURE RANGE	:-20 TO +60° C	
TEST VOLTAGE	:AT 4.8V	:AT 6.0V
OPERATING SPEED	:0.24sec/60° AT NO LOAD	:0.2sec/60° AT NO LOAD
STALL TORQUE	:7.7kg.cm(106.93oz.in)	:9.6kg.cm(133.31oz.in)
OPERATING ANGLE	:45°/ONE SIDE PULSE TRAVELING 400usec	
DIRECTION	:CLOCK WISE/PULSE TRAVELING 1500 TO 1900usec	
IDLE CURRENT	:8.8mA	:9.1mA
RUNNING CURRENT	:350mA	:450mA
DEAD BAND WIDTH	:8usec	
CONNECTOR WIRE LENGTH	:300mm(11.81in)	
DIMENSIONS	:40.6x19.8x37.8mm(1.59x0.77x1.48in)	
WEIGHT	:55.2g(1.94oz)	



2.FEATURES

3-POLE FERRITE MOTOR
DUAL BALL BEARING
LONG LIFE POTENTIOMETER
3-METAL GEARS & 1-RESIN METAL GEAR
HYBRID I.C

3.APPLICATIONS

AIRCRAFT TO 1/4 SCALE
30 TO 60 SIZE HELICOPTERS
STEERING AND THROTTLE FOR 1/10TH & 1/8TH ON-ROAD AND OFF-ROAD VEHICLES