DC Wiper Motor H-Bridge Servo / Speed Controller

P/N 1020

Features:

- Dip Switch selectable mode of operation
- Both PID servo or speed controller
- Forward/Reverse operation
- 3 on board trim pots to adjust limits, PID, speed or up/down acceleration
- Soft position limits
- Shut down feature
- On board Up/Down acceleration adjustment potentiometers
- Synchronous operation (diodes are not used for conduction except during transitions)
- High Side fast over current protection
- High Power Discrete MOSFET H-Bridge configuration
- On board regulator with a +5v regulated output for powering circuitry
- Thermistor based over temperature protection
- Ultra Quiet ~15Khz Pulse Width Modulation >99% Duty cycle
- Led indicators for normal and fault condition
- Insensitive to noise on power line.
- On board voltage TVS (transient voltage suppressor)
- 12V continuously or 24v intermittent operation
- Mode 3 demo mode continuously back/forth movement within limits with speed control
Illustration 1: Shaft side view
Applications:

- Solar panel positioning
- Camera/Spotlight rotation
- Window and door opening
- Steering systems
- Torque controller for valves
- Axis movement
- Machine tools
- Cleaning equipment
- Antenna rotation

Description

The DeviceCraft wiper motor servo/speed controller is a low cost reliable solution to many geared motor projects. The H-Bridge DC motor controller consist of 4 power MOSFETs, 2 high side/low side MOSFET drivers, hall effect high side current sensor, step down regulator circuitry, micro-controller, thermistor, and miscellaneous capacitors, diodes, resistors, and connectors.

Speed control is achieved by pulse width modulating the power supply voltage. The pulse width modulator allows the motor speed to be controlled without changing the power supply voltage. The H-Bridge configuration allows the polarity of the voltage to be reversed without reversing the power supply leads. The reversing is fully solid state and allows the rate of direction change to be controlled. If reversing is not needed the reversing can still be used to quickly drive the motor to a stop.
### Specifications for (P/N 1020)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Voltage</td>
<td>10V to 24V, damage over ~30Vdc</td>
</tr>
<tr>
<td>Current Limit Setting</td>
<td>~20Amps</td>
</tr>
<tr>
<td>Over Current Response Time</td>
<td>~20us</td>
</tr>
<tr>
<td>Over Temperature On</td>
<td>80°C</td>
</tr>
<tr>
<td>Over Temperature Off</td>
<td>70°C</td>
</tr>
<tr>
<td>Startup Time</td>
<td>~2Sec</td>
</tr>
<tr>
<td>Ramp Rate (stop to full speed)</td>
<td>~0 to 4Sec</td>
</tr>
<tr>
<td>Duty Cycle</td>
<td>0 to ~99.9%</td>
</tr>
<tr>
<td>PWM switching rate</td>
<td>~15 KHz</td>
</tr>
<tr>
<td>Digital Input low</td>
<td>0 to .8V</td>
</tr>
<tr>
<td>Digital Input High</td>
<td>3.5 to 5V</td>
</tr>
<tr>
<td>Quiescent Current</td>
<td>~12mA</td>
</tr>
<tr>
<td>Note: Hall effect current sensor draws 7mA</td>
<td></td>
</tr>
<tr>
<td>Green LED draws 3mA</td>
<td></td>
</tr>
<tr>
<td>MOSFET On resistance</td>
<td>Less than 25milliohm, uses 50v MOSFETS</td>
</tr>
<tr>
<td>Reversing Delay Time</td>
<td>0 sec (depends on ramp rate)</td>
</tr>
<tr>
<td>Speed</td>
<td>70rpm at 12v, 140rpm at 24v</td>
</tr>
<tr>
<td>Rotation Degrees</td>
<td>360 degrees</td>
</tr>
<tr>
<td>Position Resolution</td>
<td>10 bits</td>
</tr>
</tbody>
</table>

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### Input/Output Pins for Model 1020:

<table>
<thead>
<tr>
<th>Pin</th>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gnd</td>
<td>Connected to common ground for potentiometers otherwise no connection</td>
</tr>
<tr>
<td>2</td>
<td>Fb</td>
<td>Positioning potentiometer output 0 to 5v</td>
</tr>
<tr>
<td>3</td>
<td>+5v</td>
<td>+5v DC output Only a small &lt;10ma of current should be drawn from this pin for powering potentiometers</td>
</tr>
<tr>
<td>4</td>
<td>Ain</td>
<td>Analog input (0v to 5v) Selects duty cycle 0-99% or PWM duty cycle digital input (depends on mode) 50k at input to ground and 50k to 5v for a 2.5v open circuit voltage.</td>
</tr>
<tr>
<td>5</td>
<td>Bk</td>
<td>Brake control line. Pull low to activate brake. 20k Pull up to 5v on board</td>
</tr>
<tr>
<td>6</td>
<td>Gnd</td>
<td>Connected to common ground for potentiometers/switches otherwise leave open</td>
</tr>
<tr>
<td>7</td>
<td>F/R</td>
<td>Digital Input Forward/Reverse selection 0v reverse 5v forward 20k Pull up to 5v on board With servo modes this inverts the direction when tied to ground.</td>
</tr>
<tr>
<td>8</td>
<td>Is</td>
<td>Current sense output Increases with increasing current no current 2.5v</td>
</tr>
<tr>
<td>9</td>
<td>Stdw</td>
<td>Apply between 2v and 30v to shut down the unit, otherwise leave open for normal operation.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gnd</th>
<th>Gnd</th>
<th>1/4” quick connect ground for unit Use &lt;= 18 AWG wire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>Power</td>
<td>1/4” quick connect 10v to 24v power supply input Use &lt;= 18 AWG wire</td>
</tr>
</tbody>
</table>
Illustration 2: Mode
Selection DIP switch
<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td><strong>PID servo MODE</strong>&lt;br&gt;Analog input Ain (0v to 5v) determines position&lt;br&gt;Lim Trim Pot controls positioning limits&lt;br&gt;I/Up Trim Pot controls Integral&lt;br&gt;D/Dwn Trim Pot controls differential&lt;br&gt;F/R line inverts movement&lt;br&gt;Brake Line (when low) brakes the motor, shorting motor to ground</td>
</tr>
<tr>
<td>1</td>
<td><strong>P servo MODE</strong>&lt;br&gt;Analog input Ain (0v to 5v) determines position&lt;br&gt;Only uses proportional control but, allows for a large proportional multiplier.&lt;br&gt;Lim Trim Pot controls positioning limits&lt;br&gt;D/Dwn Trim Pot controls Proportional Multiplier&lt;br&gt;I/Up Trim Pot controls maximum duty cycle&lt;br&gt;F/R line inverts movement&lt;br&gt;Brake Line (when low) brakes the motor, shorting motor to ground</td>
</tr>
<tr>
<td>2</td>
<td><strong>Duty Cycle/Speed Control Separate Forward/Reverse line</strong>&lt;br&gt;Ain controls duty cycle (0 to 5v)&lt;br&gt;0v stop, 5v full speed&lt;br&gt;Limit Potentiometer sets movement limits, if limit potentiometer close to zero no limits are used (for continuous rotation)&lt;br&gt;I/Up Trim Pot controls ramp up rate&lt;br&gt;D/Dwn Trim Pot controls ramp down rate&lt;br&gt;F/R line reverses movement&lt;br&gt;Brake Line (when low) brakes the motor, shorting motor to ground</td>
</tr>
<tr>
<td>3</td>
<td><strong>Forward/Reverse on one analog input</strong>&lt;br&gt;Ain controls duty cycle (0v to 5V)&lt;br&gt;2.5v stop, 0v full reverse, 5v full forward&lt;br&gt;I/Up Trim Pot controls ramp up rate&lt;br&gt;D/Dwn Trim Pot controls ramp down rate</td>
</tr>
</tbody>
</table>

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Limit Potentiometer sets movement limits, if limit potentiometer close to zero no limits are used (for continuous rotation)

When F/R line is placed low, Demo mode for continuous back and forth movement

| 4 | Forward/Reverse on one analog input  
Ain controls SPEED (0v to 5V)  
2.5v stop, 0v full reverse, 5v full forward  
This mode controls the speed of the motor, adjusting the duty cycle to obtain the desired SPEED. Samples the position potentiometer to calculate the speed at intervals.  
I/Up Trim Pot controls ramp up rate  
D/Dwn Trim Pot controls ramp down rate  
Limit Potentiometer sets movement limits, if limit potentiometer close to zero no limits are used (for continuous rotation)  
F/R line is inactive |
|^ 5 | PCM PID servo mode.  
PCM digital pulse on Ain Line  
1.5msec 180 degrees, 1msec 0 degrees, 2msec 360 degrees  
Lim Trim Pot controls positioning limits  
I/Up Trim Pot controls Integral  
D/Dwn Trim Pot controls differential  
F/R line inverts movement  
Brake Line (when low) brakes the motor, shorting motor to ground |
|^ 6 | PCM Proportional servo mode.  
PCM digital pulse on Ain Line  
1.5msec 180 degrees, 1msec 0 degrees, 2msec 360 degrees  
Lim Trim Pot controls positioning limits  
D/Dwn Trim Pot controls Proportional Multiplier  
I/Up Trim Pot controls maximum duty cycle  
F/R line inverts movement |

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Brake Line (when low) brakes the motor, shorting motor to ground

| 7 | PCM speed control mode.  
|   | PCM digital pulse on Ain Line  
|   | 1.5msec stop, 1msec full reverse, 2msec full forward  
|   | Limit Potentiometer sets movement limits, if limit potentiometer close to zero no limits are used (for continuous rotation)  
|   | I/Up Trim Pot controls ramp up rate  
|   | D/Dwn Trim Pot controls ramp down rate  
|   | F/R line reverses movement  
|   | Brake Line (when low) brakes the motor, shorting motor to ground

LED indicators:

1) Green LED
   A) Continuously ON – normal operation
   B) Off during shutdown or no power

2) Red LED.
   A) On start up flashes the number to times to indicate the selected mode.
   B) Flash 1 second interval – Over temperature active
   C) Flash ¼- 1/2 second interval – Over Current active

Power Handling

The motor controller will handle the maximum current required by the motor. The maximum stall current under full load is ~8Amps at 12Volts and ~16Amps at 24Volts.
Acceleration

The acceleration is controllable from 0 seconds to ~5 seconds. A controlled acceleration reduces wear on the motor, gears, and power source. A controlled acceleration can prevent the over current protection circuitry from triggering during start-up or reversing. The acceleration can be controlled by adjusting the on board potentiometers.

There are 2 on board potentiometers. The top potentiometer, labeled I/up, controls the ramp up acceleration. The bottom potentiometer, labeled D/dwn, controls the down acceleration.

Braking

The motor controller has a brake operation for most modes. Braking is activated by pulling the brake line low. If braking is not needed then the brake control line can be left open due to the on board pullup resistor. During braking the pulse width modulator is disabled and both lower MOSFETs are continuously turn on till the brake line is pulled high. Initially during braking the current in the motor series inductor is decayed in a slow decay mode till the current dies down. After the current dies the motor experiences a short, building up current in the opposite direction. If held low the motor will quickly come to a stop. Pulsing the brake line can be used for regenerative braking, the required pulse width depends on the motor characteristics, speed, and desired braking current.

Braking can be used to stop the motor once the desired position has been reached. Braking will help prevent current draw on the power supply and bouncing in servo mode.

Shutdown

Shutdown mode will reduce the idle power supply current consumption. The shutdown mode is currently activated by driving the shutdown pin with a logic high up to the power supply voltage.

Over Current Protection:

The H-Bridge motor driver provides for over current protection. The current is sensed with a Hall Effect sensor located on the +V power supply line. The sensor is placed strategically between the large capacitor and the H-Bridge. The placement before the large +V capacitor would not allow for quick capture of over current conditions. The output of the Hall Effect current sensor also is routed to the 10 pin control connector. The normal 0 ampere output of the sensor is 2.5 volts. With an increase in current the output increases. When in regeneration mode the voltage will drop below 2.5 volts. The
current protection is hardware based and is always monitored. When an over current level is met, all the MOSFET switches in the H-Bridge are shut down (coast). In a case where the motor outputs are shorted the protection circuitry will shut down within about 20usec. The over current is monitored by the microprocessor and will normally reset in ½ a second. The RED will flash at ¼ second intervals.

**Over Temperature Protection:**

The over temperature protection trigger can also be modified. Currently the voltage is monitored at a junction in between a 10k thermistor TC1 and a 20k standard resistor R7. To increase the temperature limit lower the value of R7. Increasing the temperature limit can be achieved by lowering R7 from 20k to a lower value by soldering a extra 0805 chip resistor in parallel with R7 or by replacing the resistor with a lower value.
Ain input filtering

There is an Ain input filter. The filter filtering is controlled by R21 and C11 and any external potentiometer resistance. R21 is currently a 24 ohm resistor and C11 is .1uf. The modifying the C11/R21 combination will change the filter. Most voltage spikes from the motor controller which could be coupled to the Ain line are in the <2usec range. The acceleration feature should also be factored into any filtering scheme.

Note also R14/R15 is installed to set the open circuit voltage, appearing after the filter. Modifying the input resistance R1 and divider R15/R14 can also useful for setting an maximum speed control.

Illustration 3: Ain Filtering and Offset

Digital Input Filtering

There is software based filtering on the digital input lines. Currently the Br(brake) and F/R(forward/reverse) lines are the 2 digital inputs. Each line has a 20kohm pullup to +5v. The lines are most susceptible to noise during the low state which triggers at about .8volts. The software samples each line multiple times and determines if a change condition has occurred. Most noise appearing on the line occurs during MOSFET transitions magnetically and static coupled input the high impedance inputs. The motor and MOSFET noise is usually in the <2usec range. If long line are needed then shielding the digital input lines may help. Adding a capacitor at inputs can also improve noise rejection.

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Regeneration

The motor controller can achieve the regeneration function. Regeneration is a difficult subject to discuss briefly. During regeneration the motor acts as a battery in series with a large inductance, usually of many milli Henry. The motor's internal inductance is a key factor. The inductance is used to act as a inductor in a DC-DC converter. Current is built up in the inductor when shorted. When the short is opened the inductor will produce a very high voltage, higher than the supply voltage. The voltage is limited by the battery or in worst case the on board TVS.

In a large motor situation regeneration should be performed with care. Do not reverse the motor till the motor has slowed. Settling a proper deceleration is necessary. Find a low Ain(speed setting) to generate a smooth regenerative current the battery can handle. This method is synchronous allowing for the least losses and is adjustable. As the motor slows the Ain(speed setting) can be reduce to increase the regenerative current. The voltage on the brushed DC motor is proportional to the speed(RPM). As the motor slows the motor voltage will decrease requiring the short to remaining on proportionally longer on time than high side MOSFETs to generate the same current.

The other method of achieving regeneration is to pulsing the brake and coast lines. This method is not synchronous since during the coast mode the diodes in the upper and lower MOSFETs will conduct. The diode voltage drop is normally much high then the voltage when the MOSFET is ON creating much more heat.

If the motor terminals are disconnected during regeneration the on board TVS then the motor controller may be damaged by over voltage. TVS's(transient voltage suppressor) usually short then fuse.

Power Supply Inputs:

1) V+ Input powers the motor and control circuitry. Do not reverse the V+ and ground, reversing the power supply will damage the power MOSFETs. The power MOSFETs have an internal diode from the source to the drain. Consider using thick solid wire of at least 20AWG. Stranded wire should be used with care. The motor and terminal screw terminal will except wire down to 12AWG.

2) Gnd input is the unit ground. This input is also tied to the 10 pin control connector Ground inputs.

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## Wire Resistance Table

<table>
<thead>
<tr>
<th>AWG</th>
<th>Diameter</th>
<th>Resistance per foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>20 mils (thousands of inches)</td>
<td>26 milliohms</td>
</tr>
<tr>
<td>22</td>
<td>25 mils</td>
<td>16 milliohms</td>
</tr>
<tr>
<td>20</td>
<td>32 mils</td>
<td>10 milliohms</td>
</tr>
<tr>
<td>18</td>
<td>40 mils</td>
<td>6.2 milliohms</td>
</tr>
<tr>
<td>16</td>
<td>50 mils</td>
<td>4 milliohms</td>
</tr>
<tr>
<td>14</td>
<td>64 mils</td>
<td>2.5 milliohms</td>
</tr>
<tr>
<td>12</td>
<td>80 mils</td>
<td>1.6 milliohms</td>
</tr>
</tbody>
</table>

## Dimensions

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Illustration 4: Hookup diagrams for complex and simple