HP07 Digipot Interface Module

Overview:

The module is designed to provide an easy to use interface for the industry standard Up/Down interface based digital potentiometers. The module accepts either parallel or serial input, depending on a mode select pin's voltage, from the user to get 8 bit data based on which the digital potentiometer is adjusted. The module abstracts the comparatively tedious 3-wire up/down interface from the user and provides easier access to controlling the resistance digitally.

Features of the Module:

- Resistance can be digitally set* to the required value without any manual labor unlike ordinary potentiometers. For manual setting, the on-board DIP switch can be used to set the resistance to the required value without any measurement (to set the resistance in an ordinary potentiometer, the resistance has to measured and accordingly the potentiometer knob is rotated)

- The module is 5V/3.3V compatible making it suitable for interfacing with all microcontrollers and development boards like the 5V Arduino and 3.3V MSP430.

- The interface can be set to either parallel or serial by asserting the P/S' pin on the module. The serial or parallel modes can be changed during run-time without powering down.

- Parallel input can be supplied from a digital circuit through the header pins or using the on-board DIP switches depending on a jumper position.

- Compatible with a range of industry standard digital potentiometers.

*For the procedures of the various operations of the module, refer page 4 and 5.

Necessities & Uses of Digital Potentiometers:

Digital potentiometers are digitally controlled devices that can be used to adjust voltage or current and offers the same analog functions as a mechanical potentiometer or rheostat. This allows an automatic calibration process that is more accurate, more robust, and faster, with smaller voltage glitches. Digital potentiometers are often used for digital trimming and calibration of analog signals and are typically controlled by digital protocols, such as I2 C and SPI, as well as the up/down protocols. A digipot with a parallel interface is almost non-existent in the market. This module is designed to fit that requirement.

Typical application diagrams of the digipot are shown below.

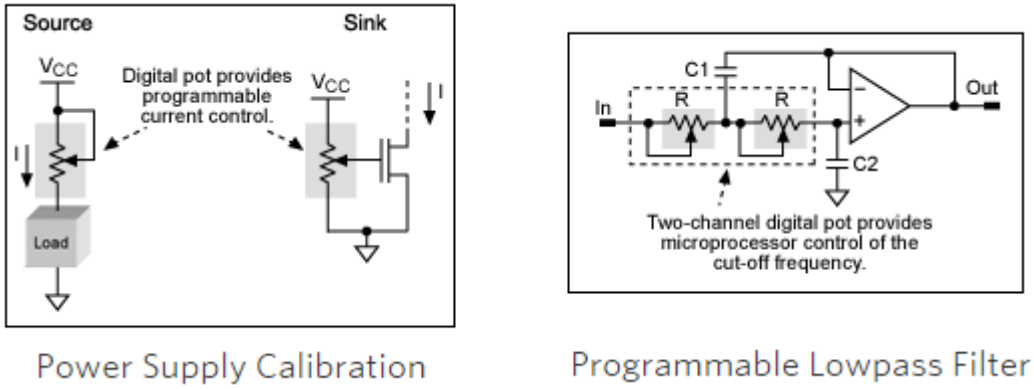

Figure 1. Typical Application Diagrams involving the MAX1804 (from Maxim Integrated Inc.) digipots

Digipots are also very useful in setting programmable gain functions in instrumentation, isolation amplifiers etc. This provides a much more diverse performance than the available currently available Programmable Gain Amplifiers (PGA). Thus it is beneficial to use digipots in many applications where a physical parameter like resistance has to be digitally controlled. Therefore, this digipot module is designed to provide an all-in-one solution to using the following suggested parts.

Resistance\Voltage	0 to +5V	-5V to +5V
1kΩ		X9C102
10kΩ	DS1804-010	X9C103
50kΩ	DS1804-050	X9C503
100kΩ	DS1804-100	X9C104

Digipot IC:

The DS1804 series comes from Maxim Integrated and the X9C series comes from Intersil. All these parts are the same 8 pin DIP IC's with standard compliant pin configuration as below.

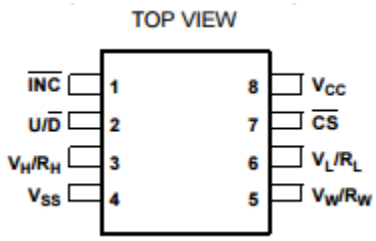

Figure 2. Common Pinout Diagram of the suggested module compatible ICs

There are four sections inside these digipot ICs-the input control, counter and decode section; the non-volatile memory; and the resistor array. The input control section operates just like an up/down counter. The output of this counter is decoded to turn on a single electronic switch connecting a point on the resistor array to the wiper output. Under the proper conditions, the contents of the counter can be stored in non-volatile memory and retained for future use. The resistor array is comprised of 99 individual resistors connected in series. At either end of the array and between each resistor is an electronic switch that transfers the potential at that point to the wiper. The wiper, when at either fixed terminal, acts like its mechanical equivalent and does not move beyond the last position. That is, the counter does not wrap around when clocked to either extreme. The electronic switches on the device operate in a "make-before-break" mode when the wiper changes tap positions. The RTOTAL value for the device can temporarily be reduced by a significant amount if the wiper is moved several positions. When the device is powered-down, the last wiper position stored will be maintained in the non-volatile memory only if CS is pulled high. When power is restored, the contents of the memory are recalled and the wiper is reset to the value last stored.

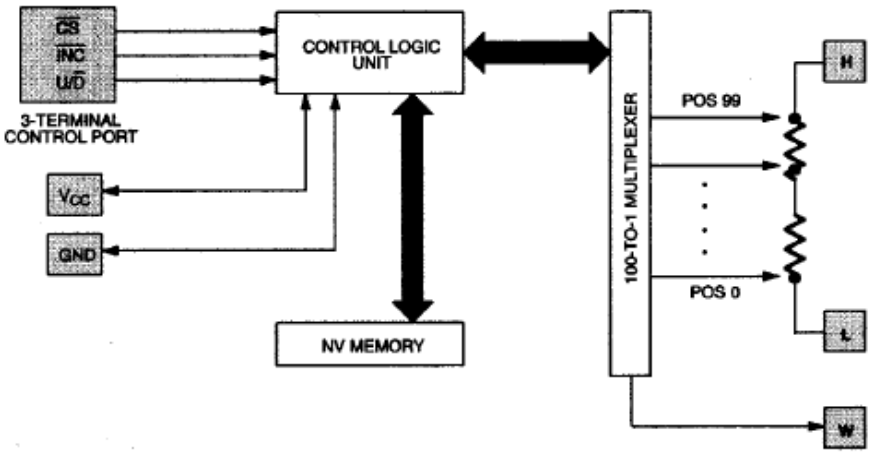

Figure 3.Block Diagram of the Digipot IC

General Procedures:

Parallel Data from external logic:

- Jumpers 1 and 2 are connected
- P/S' pin has a pull-up so it can be left unconnected for parallel mode selection.
- 7 bit data from external logic is connected to P0-P6 in the left hand side headers with P0 being the LSB.
- Depending on the 7 bit data, the wiper position changes from position 0 – 99 (0b1100011) resulting in the proportionate resistance on V_w pin and pad. If the digipot IC used is a 1kΩ digipot like X9C102, then a value of 0b0110010 applied would make the V_w pin and pad have a 500Ω reading with respect to V_L & V_H.

Serial Data from external logic:

- Jumpers 1 and 2 are connected
- P/S' pin is pulled low by external logic to select serial mode
- The clock signal is provided to CLK pin.
- Serial data line is provided to DIN pin and data is clocked in MSB first.
- The module accepts 8 bit data but processes only the 7 LSB bits.
- Depending on the 7 bit data, the wiper position changes from position 0 – 99 (0b1100011) resulting in the proportionate resistance on V_w pin and pad. If the digipot IC used is a 10kΩ digipot like X9C103, then a value of 0b0110010 applied would make the V_w pin and pad have a 5kΩ reading with respect to V_L & V_H.

Parallel Data from on-board DIP Switch:

- Jumpers 2 and 3 are connected
- Only 7 positions from 1 to 7 are wired with 8^{th} switch on the DIP left as a 'No connect'.
- The microcontroller in the module accepts parallel data through a programmed pull-up. The DIP switch is connected in such a way that when a DIP switch line is ON, the data on that line is LOW (negative logic). Therefore for an all 0 state (0b0000000), all DIP switch lines are ON. When all DIP switch lines are OFF, it corresponds to an all '1' state or 0b1111111.
- To avoid any confusion, it is suggested to set a sample data and see the resistance that appears on the V_w pin and pad.
- Depending on the 7 bit data, the wiper position changes from position 0 – 99 (0b1100011) resulting in the proportionate resistance on V_w pin and pad. If the digipot

IC used is a 100kΩ digipot like X9C104, then a value of 0b0110010 applied would make the V_w pin and pad have a 50kΩ reading with respect to V_L & V_H.

Storing Resistance Position in NV memory:

- This works only in serial mode. If parallel mode is selected, then the current parallel data given is set as the resistor position irrespective of the value in the Non-volatile (NV) memory.
- After the required position is set, the CS pin on the module is set high for at least 20ms. The current wiper position value will be stored in the NV memory.
- After the 20ms, operations can proceed as usual. If the module is switched off and then switched on in serial mode, the last stored value sets the wiper and subsequently the module waits for the new serial data, if any.

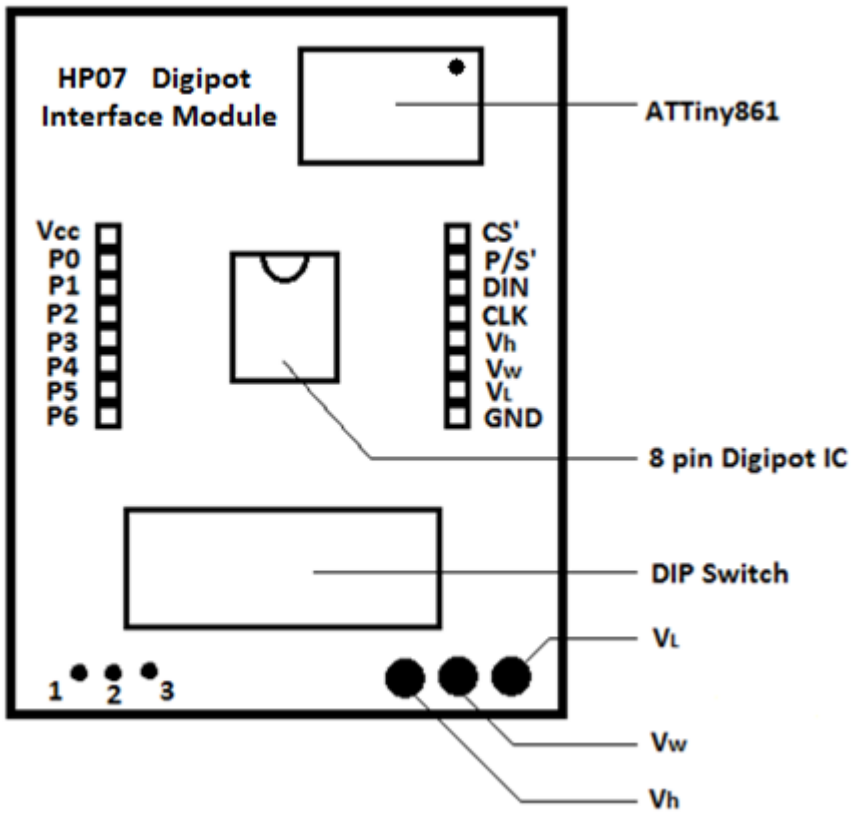

Figure 4.Physical Rubric of the Module

* 1, 2 and 3 are header pins that should be connected by jumpers. 2 and 3 are connected to enable parallel data input through the DIP switch. Connecting header 1 and 2 enables data transfer from external logic. The pads on the lower right corner are solder pads to which wires can be soldered like a mechanical potentiometer.

Timing Diagrams

Digipot IC Interface:

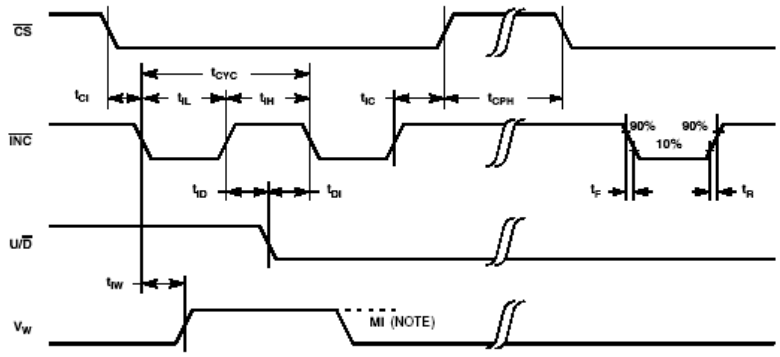

Figure 5.Timing diagram of signals between microcontroller and digipot IC

* Chip select (CS') is connected to a 10kΩ pull-down resistor on the module. As seen from the diagram CS has to be pulsed temporarily to high to store the current wiper position in the NV memory. In reality both CS' and INC' have to be kept high. However, the module keeps INC' high by default during steady state (no on-going wiper position change). Therefore all the user has to do is pulse the CS' pin for storing the data.

Module Interface with Parallel Select:

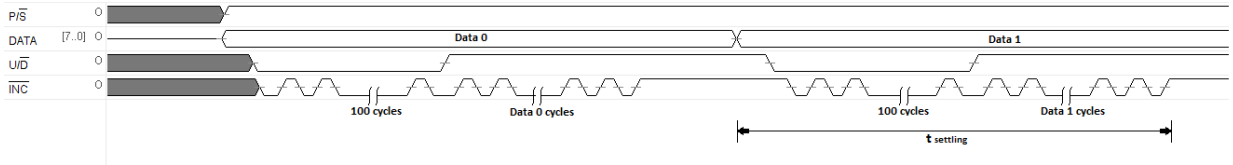

Figure 6.Timing diagram of signals from external source to and from the microcontroller in parallel mode

Module Interface with Serial Select:

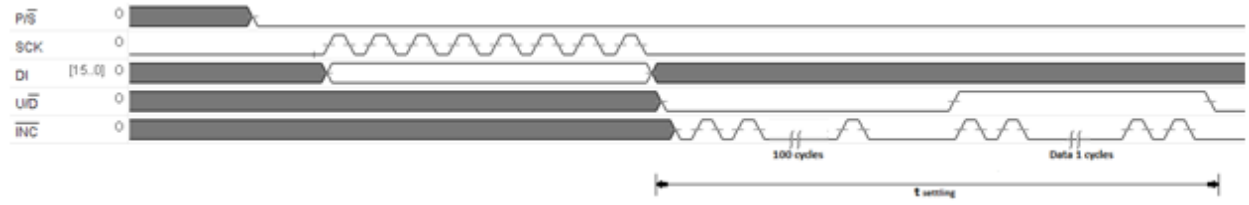

Figure 7.Timing diagram of signals from external source to and from the microcontroller in serial mode

Figure 6 and 7 illustrate the logic of the module including the 100 cycles down and then up counting depending on the user provided data. This logic is common to both serial and parallel modes.

Operational Parameters and Specifications

Parameter	Test Conditions	Limits			Unit
		Min	Typ	Max	
Vcc[1]		3	5	5.5	V
Rtotal		-20		20	%
VH	Voltage limit on VH pin	-5		5	V
VL	Voltage limit on VL pin	-5		5	V
RW	Wiper Resistance		40	100	Ω
tsettling (parallel)	Time between data read and wiper position settling	500		1500	µs
tsettling (serial)	Time between last data bit sent and wiper position settling	500		1500	µs
tCI	CS to INC Setup	100			ns
tID	INC Hugh to U/D change	100			ns
tDI	U/D to INC setup	2.9			µs
tIL	INC Low Period	1			µs
tIH	INC High Period	1			µs
tIC	INC inactive to CS inactive	1			µs
tCPH[2]	CS Deselect Time for storing	20			ms
tIW	INC to VW change		100		µs
tCYC	INC Rise and Fall time			500	µs

[1] Vcc is taken with respect to GND which should be 0V.

[2] When CS pin is externally pulled high by user to store the data, the high period width should be above this minimum limit

PCB Layout:

The schematic and PCB layout are generated using EagleCAD based on the logic discussed. The schematic and layout are seen in Figures 8 and 9.

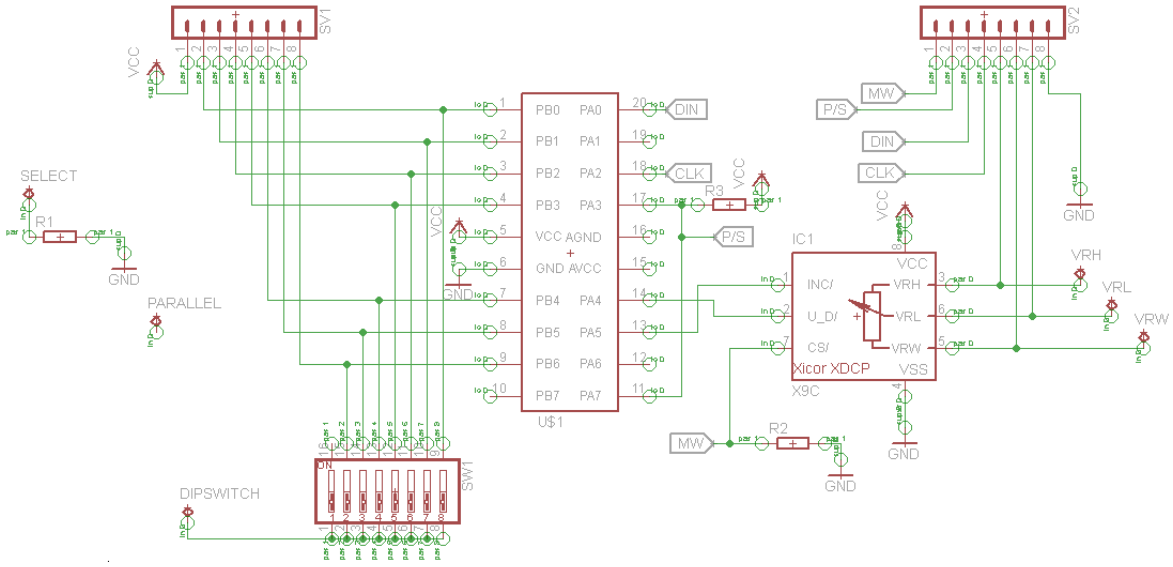

Figure 8. Schematic of the module

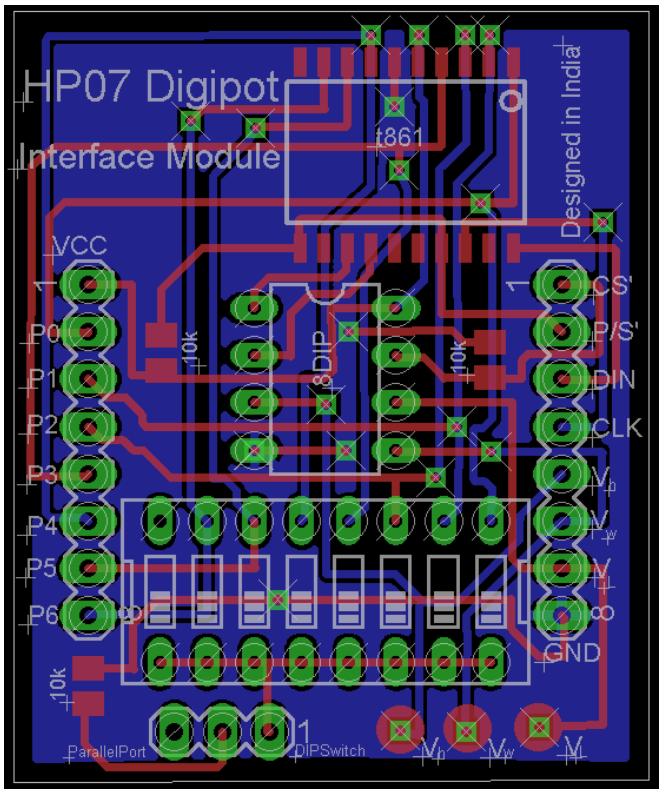

Figure 9. PCB Layout of the module

Concluding remarks

The module is designed to be an all-intents and purposes way of interfacing the industry standard up/down counter based digipot IC's. The parallel/serial interface enables data to be given to the IC in flexible ways. The on-board DIP switch is used to precisely set resistor values by using binary numbers. This comes as a great advantage especially when precise resistor values are to set. In a conventional potentiometer, setting a particular resistance is nearly impossible without measuring it. However, the on-board DIP switch enables the module to work like a conventional potentiometer without needing any external logic and still use a digipot IC to set precise resistances. This and other features justify the design of being an all intents and purposes digipot interface module.