Simple Az-El Antenna Control

Control your Antennas with a Digital Pot
by Anthony Monteiro, AA2TX, AA2TX@amsat.org

Introduction
Automatic antenna tracking makes working the amateur satellites much easier, especially on fast moving LEO satellites. But automatic tracking requires a computer rotor-control interface and this has generally been expensive to buy or fairly complex for a homebrew project. This article describes an alternative approach that uses only a single chip and is very easy to construct. The chip costs $1.59$ and the total cost of the parts is about $5$.

This interface was implemented on an azimuth/elevation satellite tracking system made from ORBIT-360 TV antenna rotators hard to find and new-old-stock units can often be found on popular on-line auction sites at very low prices.

Unfortunately, the ORBIT-360s were not designed for computer control and they have no provisions for it. But, they use a feedback potentiometer at the rotor to provide positioning information and this makes it easy to build a simple and low-cost computer interface for them. The key to this low-cost interface is a device called a digital potentiometer.

Digital Potentiometer
A digital potentiometer (pot) is a resistor with an adjustable tap just like the familiar volume control. But, unlike a volume control, the tap on a digital pot is adjusted via a digital interface rather than a knob. The device used in this rotor interface is a Microchip MCP41010, a 10K ohm pot with a built-in Serial Peripheral Interface (SPI.) SPI was invented by Texas Instruments as a simple and low-cost way for a micro-controller to communicate with its peripheral devices. Fortunately, the SPI signal levels are compatible with the signal levels on a PC parallel port. With a little bit of software to implement the communications protocol, the SPI digital pot can be controlled from a PC with no extra hardware.

The SPI protocol on the MCP41010 chip uses three signals, Not Chip Select (NCS,) Serial Clock (SCK,) and Serial Input (SI,) and is a Microchip SPI Protocol Operation. The SPI data blocks are 16-bits long and include an 8-bit command byte and an 8-bit wiper value byte. The blocks are clocked synchronously into the chip from the SI lead on positive transitions of the SCK signal.

The diagram in Figure 2 illustrates how the SPI protocol works. To start the data transfer, the NCS signal is set low. The SI lead is set to the most significant data bit value and the SCK signal is pulsed high to clock in the bit. Then the next most significant data bit value is put on the SI lead and the SCK signal is again pulsed high to clock in this bit. After all 16 bits are clocked in, the NCS lead goes high to transfer the data value to the pot wiper. For further details, please refer to the specification sheet from Microchip.

The MCP41010 will ignore any data blocks that have the wrong number of bits and this provides a high level of noise immunity. The chip also has Schmitt-trigger inputs on the SPI leads to further increase its noise immunity.

How it Works
The ORBIT-360 control box implements a closed-loop, automatic control system. A block diagram of is shown in Figure 3. The control pot on the top of the control box is used to set the desired antenna direction. The feedback pot in the rotor unit is gear-driven by the same motor that turns the antenna. The wiper on each pot forms a voltage divider from the +4.5VDC source. Each of the wipers is fed to an input of the difference amplifier circuit.

The difference amplifier compares the voltages from the two pots and generates an error signal, which is fed to the motor driver circuit. When the error signal exceeds a minimum threshold, the motor driver activates the motor, turning it either clockwise or counter clockwise depending upon the polarity of the error signal. As

![Figure 1](Satellite tracking antenna system)

![Figure 2](SPI Protocol Operation)
the software was

Motor

the parts list for the interface is in Table 1. The schematic diagram is shown in Figure 4 and the PC parallel port with a cable. The circuit enclosure. The computer interface on the any power supply, printed circuit board or rotor control box, eliminating the need for components.

The interface cable wiring is shown in Figure 7. This cable can be easily made by cutting a standard, male-to-male, PS/2 keyboard- extender cable in half and soldering the wires to a DB-25 female connector. This eliminates the need to solder the 6-pin mini-DIN male connectors, which can be a challenge given their small size.

Software

All of the software and source code is in the file irotor.zip that is available from the AMSAT web site. The software was tested and operated properly under DOS-5, Windows3.1, Windows95 and WindowsXP. The software package includes the following components; Digipot.exe, RotorDRV.exe, Rotor.exe, Park.bat and Source.zip.

Digipot.exe is a simple DOS program that will control a Microchip MCP41010 or MCP4050 digital pot. It is intended to allow experimenting with these devices which can be both fun and educational. You can use digital pots to control many types of electronic circuits well beyond the simple rotor interface described in this article. To use the program, wire the digital pot NCS, SCK, and SI leads (pins 1, 2 and 3) to your PC parallel port connector pins 2, 3 and 4 respectively and connect the circuit ground to pin 18 on the parallel port connector. Digipot.exe defaults to using port 1 but it can drive any standard parallel port by specifying the port number on the command line.

RotorDRV.exe is a TSR driver for the rotor interface that is compatible with the Kansas

Figure 3

ORBIT-360 control system

Figure 4

Computer interface schematic

Figure 5

Bottom of unmodified controller board

the motor turns, the wiper on the feedback pot moves in tandem so that eventually, the feedback pot wiper and the control pot wiper will have the same output voltage. At that point the error signal will go below the minimum threshold and the motor driver will shut off the motor. The antenna is then pointing in the direction that was set by the control pot.

To make the ORBIT-360 computer controlled, all that is needed is to replace the manually-operated control pot with a digital pot. The digital pot is wired in parallel with the control pot and a switch is used to select the wiper of either the control pot or the digital pot allowing either manual or computer control.

Circuit Description

Rather than build an external box, the computer interface was built right into the rotor control box, eliminating the need for any power supply, printed circuit board or enclosure. The computer interface on the rotor control box is directly connected to the PC parallel port with a cable. The circuit schematic diagram is shown in Figure 4 and the parts list for the interface is in Table 1.

Note that a full Az/El system requires two interfaces, one for each control box. The SPI signals on the digital pot are wired to a 6-pin mini-DIN connector that is installed at the rear of the control box. This connector is the same type used for the PS/2 mouse and keyboard on many PCs. The three 10K resistors pull down the SPI leads if the cable is disconnected from the computer. While not used on the prototype models, 100 ohm resistors may be added in series with the SPI signals for additional static protection if the units will be used where significant static electric discharge is a problem.

To install the computer interface, the pc trace from the control pot wiper to the difference amplifier must be cut and a switch is added to select either the control pot wiper or the digital pot wiper. This trace and cut is shown in Figure 5. The +4.5V and ground signals are also available right at the control pot leads making it easy to connect the interface. The modified unit can still operate stand-alone by switching to the manual control pot.

The digital pot, resistors and the capacitor were wired with 30-gauge wire-wrap wire. A photo of the completed controller board is shown in Figure 6. The 8-pin DIP on the right of the control pot is the difference amplifier, a uA741 op-amp. The 8-pin DIP on the left is the digital pot with its associated components.

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Rotor.exe is a command line control program for the RotorDRV.exe TSR. It is mostly intended for testing the rotor interface and software installation but also includes a helpful “flip antennas” feature that causes the elevation rotor to operate beyond 90 degrees (i.e. with the antennas flipped over.) This is useful when a satellite pass would cause the rotor interface to hit up against the end stop. Anyone who wants to write their own software for the rotor interface or for controlling digital pots is welcomed and encouraged to use the source code.

Operation with InstantTrack
To use the rotor driver you have to load it into memory first. This can be done by typing “rotordrv.exe” plus any options at the DOS prompt or it can be put into a batch file for convenience. Next, load any other TSR drivers that you usually use (such as OrbitDRV or InstantTune10) and then start InstantTrack. When you select a satellite and hit the “r” key to start tracking, the rotor control boxes will light up showing that the rotors are moving to track the satellite. Once they are pointing at the correct azimuth and elevation, the lights will go out. As the satellite pass progresses, the lights will flash when one of the rotors is moved to track the satellite. This system will track a satellite to within about 2 degrees which is more than sufficient for pointing a 1-meter dish at 2.4 GHz. The RotorDRV software will automatically suspend rotor movement if the satellite elevation goes below -5 degrees.

Summary
Digital potentiometers are very useful and provide an incredibly easy way to control an analog circuit from a PC. The rotor interface described in this article was built for about $5 using a handful of commonly available parts. Although simple and inexpensive, this rotor interface provides all the hardware needed for fully automatic antenna tracking and greatly simplifies operating on the ham satellites.

Endnotes
1 LEO: Low Earth Orbit
2 MCP41010 is listed at $1.59 each at Jameco Electronics; www.jameco.com
3 TV antenna rotators with 3-wire connections do not use a pot and will not work with this circuit
4 A Panel Reflector Antenna for 70cm, by Anthony Monteiro, AA2TX, QST Feb 2005.
5 Microchip spec sheets can be found at www.microchip.com
6 rotor.zip software is available at www.amsat.org
7 TSR: Terminate and Stay Resident program, a way to effect hardware drivers under DOS
8 The Kansas City Tracker interface spec is available from AMSAT at www.amsat.org
9 InstantTrack is available from AMSAT at www.amsat.org
10 InstantTune automatic radio tuning software is available for free from AMSAT at www.amsat.org

Table 1
Parts List

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>0.1uF, 50V ceramic disc capacitor</td>
</tr>
<tr>
<td>J1</td>
<td>6-pin, mini-Din jack</td>
</tr>
<tr>
<td>R1, R2, R3</td>
<td>10K ohm, ¼ watt resistor</td>
</tr>
<tr>
<td>S1</td>
<td>SPDT sub-miniature toggle switch</td>
</tr>
<tr>
<td>U1</td>
<td>MCP41010, Microchip digital pot</td>
</tr>
</tbody>
</table>

Park.bat is a DOS batch file that will park the rotors with the antennas pointing straight up. It can be easily modified using a text editor such as Notepad or WordPad to set the parking position to wherever is desired.

Source.zip is the source code for the Digipot.exe, RotorDRV.exe and Rotor.exe programs.

City Tracker8 specification. When installed, it uses only 6K of memory and can control azimuth-only or Az/El rotor systems. It was designed for and has been tested with TV antenna rotators with 3-wire connections.

The software modules include a parallel port driver, an SPI digital pot driver and a rotor controller. Anyone who wants to write their own software for the rotor interface or for controlling digital pots is welcomed and encouraged to use the source code.