

A Beam Position Indicator Project
Versions 8.40(soft clock), 9.51(4 line, hard clock) and 10.0(hard clock)
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This project describes a complete azimuth and elevation readout system that outputs to array driving motors. Motor movement may be initiated by either front panel switches, internal calculations of moon or sun positions or by external computer control. The system interfaces to the satellite prediction program 'Orbitron' and VK3UM's EME Planner. A GPS may be used to enter Date/Time and Lat/Long. Currently the system works with the following different position sensors:

- *Home made encoder using either an AS5040 (10 bit) or AS5045 (12 bit)*
- *A screwjack*
- *The MA3-12 series from US Digital*
- *HH-05 and HH-12 from DF1SR*
- *Megatron's MAB25 (10 bit), while the MAB25A (10/12 bit) and the MAB36A (12 bit) should work but are untested*
- *The A2 and A2T encoders from US Digital through the SEI to RS232 adapter AD2-B*
- *Linear potentiometers*
- *The COA1E8C16 encoder (10,12,14,16 bit versions)*
- *SCA61T inclinometer chip (see my website for details)*
- *Yaesu AZ/EL rotator with or without the GS232A computer control*

With the addition of the SCA61T I have decided to overcome the limitations of 64K in the 18F4620 by moving to an 18F4682 with 80K memory or the 18F4686 with 96K memory. Pin connections are the same as the 18F4620. Version 7.00 software is still fine for the 18F4620/4680. Main improvements in the 18F4682/85 code are improved EME Doppler calculation and inclinometer support and a 4*40 line display in V9.51.

I will cease development of the software clock version from Version 8.40 to minimise my workload. Supported versions will be the 9.50+ for 4 line displays and version 10.0+ for 2*16 displays both with hardware clocks (DS1307 from Futurlec). At this point (11 June 2010) all three versions offer identical facilities except for the type of clock and display.

Introduction

The traditional method of determining the direction of a beam is to use a linear potentiometer driven by a gearing system to convert 360 degrees to the 270 degree motion of the potentiometer. A bridge circuit with a calibrated meter enables the direction to be read out. The potentiometer method has the advantage of providing an 'absolute' reading. That is, on power up it will immediately provide a beam heading without calibration. If you're lucky you might achieve 4 or 5 degree accuracy.

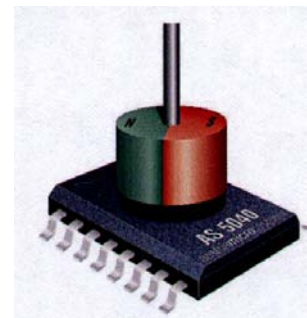
Originally the project was not designed to support incremental encoders but many requests led to support for the screwjack. 'Incremental' indicators rely on calibration each time the unit is turned on. See the separate manual "Manual for Screwjack Solution.pdf". The same boards are used but a different program is used in the antenna unit and interfacing is modified to suit the screwjack. One advantage is that the AZ/EL boards can be placed in the shack.

A common method used by those who require greater precision than that provided with a potentiometer system is to use a Gray coded wheel. The Gray code is a binary code that unlike the standard binary count changes just *one binary digit at a time*. For example in standard binary a count proceeds like this: 0000, 0001, 0010, 0011, 1000, 1001, 1010, 1011 etc.

In Gray code the count proceeds like this: 0000, 0001, 0011, 0010, 0110, 0111, 0101, 0100 etc

A Gray coded wheel may have any number of bits - in practice ≤ 16 and in practical terms for amateurs < 13 bits. The lines on the perimeter need to be very fine once 12 bits is reached, and for amateur constructors may require a fairly large diameter wheel (eg 150-300mm). A Gray coded wheel has LEDs and photosensitive detectors to read out the active bits. The light source and detectors must be well aligned and use a fine slot to overcome ambiguous readings (hence the use of Gray code to overcome ambiguities). They are not a trivial device to make.

When first drafted, this manual described the application of the new AS5040 chip from AustriaMicrosystems. The AS5040 uses 1024 hall affect sensors to determine the location of a magnetic field and thereby provides a 10 bit output that equates to 0.34 degree definition. A special diametral (2 * 2 poles) magnet produced by Swiss Company Bomatec AG is the rotary component of the system.



The AS5040 was produced to provide the radial location of steering wheels, accelerator pedals etc in fly by wire applications. The chip is capable of providing accurate readouts without missing a location on a shaft rotating at 600RPM. It is not anticipated that the capabilities of the chip will be stressed by beam rotation speeds! The chip samples each location at 12KHz.

Position is determined by a rotating, small diametral magnet (6mm * 2.5mm) using NdFeB alloy. It is nickel coated as the material is quite brittle. The magnet is placed 1-3mm above/below the AS5040 chip and an alignment better than 0.25mm. Fortunately the chip supports a calibrate mode to allow fine adjustment. The AS5040 is a small surface mount device and measures about 6mm*5mm. The chip manufacturer's website is <http://www.austriamicrosystems.com/04segments/industry/AS5040.htm>

Originally designed to use the AS5040 encoder and as an electronic solution to beam indicators, the project has since grown to cater for a variety of encoders and thanks to the separate AZ/EL boards considerable flexibility in encoder choice is available.

The AS5040 (10 bit =1024 positions) has been superseded in some respects by the AS5045 (12 bit = 4084 positions) but a number of commercial encoders now use one of the two chips to provide 10 or 12 bit options. Frankly, using one of the commercial units makes construction and alignment much easier. See my website for comments on accuracy for each encoder and the moon/sun calculations.

I continually update my website with new encoders and the software is also in constant BETA as my enjoyment comes from experimenting with and improving it.

How the masthead encoders are physically connected to the antenna system is for your own ingenuity as every system is different. The general project description is the same for all encoders, the differences are in the programs for the AZ/EL units. The Shack Unit is menu adjustable for the different definitions provided by the encoders.

Although primarily designed as a moderately high definition system for EME work, as the project developed it became obvious that it would also be useful for those amateurs using terrestrial communication and whose rotator control unit was missing or unsuitable.

See my website <http://vk5dj.mountgambier.org/Beam/Beam.html> for further information on the use of all encoders. This manual uses the AS504/45 solution for explanation but is relevant for all encoders. Some use the AS5040/45 internally.

So what is it and how does it work?

The beam indicator system displays azimuth and elevation headings for an antenna system. It calculates the position of the sun for antenna calibration and the moon for EME experiments. The system can either auto track from internally developed data or from a computer with appropriate interface software. Tracking may also be manually controlled from front panel switches. The tracking accuracy is better than 0.5 degree using the described encoder chips.

With the aid of software averaging, the readout in the shack unit is 0.1 degree increments even for the AS5040 but less precise and less steady readout than the AS5045 with its native 0.1 resolution. Note that averaging for the system in motion must be different from that when stationary. This is catered for in menu items 28 and 29 antenna. Disregard the 'catch up' nature of the display during the bench testing phase – this is averaging at work when it would normally be off. The AS5045 will allow much smaller settings for hysteresis than will the AS5040.

The unit has a control box located in the shack and one or two masthead boxes.

The unit(s) at the masthead measures the position of the antenna to an accuracy of 1:1024 or about 1/3 of a degree for an AS5040 or 1:4096 or about 0.1 of a degree for the AS5045. The reading is 'absolute' meaning that the antenna does not have to be sent back to a starting point in order to recalibrate if the power disappears. Readers who want more information on accuracy are urged to read my website for further detail.

On receiving a request from the shack unit the masthead unit sends its data to the control unit in 9600 baud ASCII. If elevation measurements are required, a separate elevation unit sends serial data to the shack unit upon reception of a controller poll.

The shack located, control unit has a PIC controller chip that receives the serial input from the masthead units and displays the azimuth and elevation positions. The control unit can operate in either manual (local control) or auto (computer control) mode as determined by a front panel switch. Further switches determine if the position calculated is that of the sun or moon and whether it is calculated internally or externally. External calculations enable satellite tracking (driver support for Orbitron is provided). The control unit may be set to delay antenna movement when the direction reverses to avoid undue stress on antenna elements and the rotator itself. Software travel stops are also provided.

The output of the PIC18F4682/85 drives five transistors (4 directions and a brake) which in turn drive five relays that provide power and direction control.

In addition to receiving signals from a serial source, the project is designed to accept input from a potentiometer like those in most rotators. The variable voltage from a potentiometer wiper is directed to A/D converters that may be translated to a beam heading. Some rotators use a rheostat so some modification may be required to produce the voltage divider effect. A reference of ground and regulated +5V is available on each DB9 for potentiometers.

The unit may be setup to allow for readings below the horizon, whether there are one or two sensors, presence of a brake, variable delay before direction change, input type (serial or pot), whether the pot sensors cover more than 180 or 360 degrees and crossover points. After initial programming the operational conditions can be varied by accessing menu mode from the front panel switch.

The masthead unit

The masthead unit uses a 16F628 PIC to query 10 bit data from the AS5040 (12 bit from an AS5045), which it then assembles into a packet of information and sends to the shack unit serially using 9600 baud, 8 data bits, 1 stop bit ASCII.

The antenna azimuth and elevation units are identical.

Two circuit boards support the AS5040/45 sensor at the masthead. (Note that potentiometer systems require no other hardware at the antenna, while all other encoder systems such as HH-12, inclinometer, MA3-12 etc require only the AZ/EL board) The AS5040/45 board is deliberately made as small as possible to allow for different mounting methods of the AS5040 and its rotating magnet. The board contains a socket, the encoder chip and two capacitors. The magnet spins above the chip and is the only moving part. The construction makes for a device that has little to wear and is highly resistant to dust and other pollutants. See photos 2 and 3 for construction details. This board should be mounted so that its position beneath the magnet can be adjusted in the X, Y, and Z planes.

The masthead unit contains a PIC16F628 and an LM78L05 provides the 5V regulated power. An original plan to include a MAX232 chip to convert TTL levels to those more suited for serial data transfer was found unnecessary. Experiments using a 100m length of Cat 5 twisted pair cable showed TTL worked fine at the data rate chosen. Remember that if you choose to add an external MAX232 at the antenna end you will need to use another at the controller end (see later). Initially DO NOT install IC4.

The Azimuth and Elevation programs for the 16F628s are the same. The masthead units may be placed into calibrate mode (SW1 momentarily on, then off when using AS5040 but SW1 left on for AS5045). In this mode the AS5040 outputs a number that may be used to position the board under the magnet. The controller unit in the shack will display "Magnet=" followed by a number. As the magnet revolves the displayed number should vary by less than 30 for a 360 degree rotation. Fortunately this seems to be less critical than the datasheet suggests but could be an important determinant of tracking accuracy. Only J2, the azimuth DB9, is coded for use in calibration mode. The AZ/EL mode should be set to In=serial/none.

The masthead unit has another switch (SW2) supporting a 'terminal' mode providing you add a temporary inverter transistor and modify the connections on the DB9. Having done this place SW2 in the on position and connect the serial output to a computer running Hyperterminal at 9600 baud, 8 data bits, one stop bit and no parity. The unit will display

“Azimuth = XX degrees” where XX is the bearing. I used this feature to provide a demonstration at GippsTech in July 2005 before the construction of the controller unit. See Appendix 1 for connections because a computer serial port requires inverted data to operate.

SW3 on the masthead unit allows the count to be reversed to suit different mounting methods resulting in clockwise or anti-clockwise movement.

Power consumption of the antenna unit is a few milliamps. The antenna unit has four connections: Ground, 9600 baud ASCII out, handshake in, 12V power in. The recommended cable is CAT5 network cable. Cat5 has three pairs. Pair each active lead with an earth wire. **Note that the DB9 overlay is correct for a socket DB9.** If you use a plug DB9 place it on the bottom of the board.

The Controller

This shack based unit utilises 12V at up to 400mA to power relays and the board. The board has:

- LM7805 derived 5V regulated supply
- PIC 18F4682 or 18F4685 (a 40 pin device with 40K or 49K of 16 bit program memory, RAM for variables and long term data storage in EEDATA memory)
- 4066B CMOS switch to steer the incoming serial data from three sources to the USART input port on the PIC
- 1 or 2 MAX232 chips depending whether you require the second for the antenna units. Each Max232 can support two inputs and outputs. One for the computer interface is mandatory to ensure reliable comms and correct data sense. The second MAX232 is required for some computers or the SEI interface. The AZ/EL unit does not need IC4 to be installed.
- 5 TIP31C NPN power transistors to switch the relays (smaller transistors would be acceptable for relay switching).
- 5 relays with 12V coils, DPDT 10 A contacts to provide the heavy duty switching. For each of azimuth and elevation, one relay switches the windings to determine direction while the second switches power. The power relay closes 50ms after the direction relay. A speed controlled solution is being worked on, but will be a later release.

General description of the controller operation

The PIC operates at a frequency of 32MHz determined by the 8 Mhz crystal using a 4* multiply mode. This frequency is used for internal timing and must not be substituted.

The PIC sends a low active handshake signal to the masthead unit, clears its receive buffer, switches on the appropriate gate of the 4066 to transfer the data from pin 3 of the DB9 and checks the data stream for an “A” or an “M” then loads the value from the masthead unit and the checksum. If the checksum confirms the data is correct, the value is converted to degrees with one decimal place and displayed on the LCD.

In the process of conversion of the elevation raw number, the controller will allow for any below horizon measurements. This is a setup option that may be altered at any time. However, most of us won't be in that wonderful position of living on hill tops!

Assuming that both azimuth and elevation sensors are present or activated in setup, the PIC will next check the elevation sensor in a similar manner to the azimuth process.

If the front panel switch is in Auto position, the device automatically tracks the antenna, switching data as appropriate through the 4066B. If external calculations are requested then computer data becomes available after raising the CTS line to signal the computer to send. In my "Remote" software and VK3UM's Autotrack the CTS is now unused and the computer software relies on a software interrupt informing the computer of the arrival of data, on completion of received packets this in turn triggers the sent data. I recommend still wiring the CTS lead as some older software requires it.

A simple check sum is used for all data inputs and, if confirmed, sends the information to the decode section for triggering the relays. See the comments above on menu item 42.

If the front panel switch is in the manual position the relay operation is controlled by the 4 spring loaded front panel switches – up/down, left/right. The switches do not directly control the relays but are used to inform the PIC of required moves. This enables the use of a delay function to prevent too rapid a changeover of direction motors in the interests of beam survival. The delay is configurable from 0 to 6 seconds. Hysteresis may be added in 'Auto' mode to minimise hunting.

The 2 line LCD display usually displays the azimuth and elevation on the top lines while tracking information appears at the bottom. A star is appended in delay mode when the controller is waiting for the beam to come to rest. See Appendix 3 for information on the 4 line LCD display.

The LCD is also used to display the configuration states. These are accessed by putting the device in 'Update mode' by putting the Menu switch in the 'ON' position. *NOTE: the menu access is different from Version 7.00 as the Park Switch has been renamed 'Menu' and Park is now accessed from a menu setting.* Once 'Sec=' shows, the various options may be accessed using the UP/DOWN buttons, while LEFT/RIGHT increases or decreases values. Note that for values showing decimal points the normal increment and decrement is 0.01 but by putting the Calibrate Switch in the 'on' position the reading increments by whole numbers.

NOTE: the fast mode switch is different from Version 7.00 as the Park Switch has been renamed 'Menu' this required a change to the switch governing speed.

The memory is updated ONLY if data is changed and for some items ONLY when the menu moves to the next item with the 'Up' or 'Down' buttons. Returning the 'Menu' switch to manual leaves the menu and returns to normal operation. Be sure to return the "Calibrate" switch to the OFF position before returning to normal mode or you will incorrectly calibrate the system.

The order of display is: Seconds, Minutes, Hours, Day, Month, Year, Brake/limit, Delay, AZ/EL mode, AZ spread, EL spread, AZ offset, EL offset, AZ low stop, AZ high stop, EL low stop, EL high stop, AZ hysteresis, EL hysteresis, HT ASL, Longitude, Latitude, Park AZ, Park EL, AZ resolution device, EL resolution device, SCA61T calibrate, Averaging, Offset direction AZ and EL, external VGA mode (requires additional hardware), Time off/on in external mode and RS232 or TTL levels for CTS and DTR, SEI interface, Refraction ON/OFF, Relay mode, Park, Check ON/OFF. The menu system wraps.

(1,2,3,4,5,6) Seconds, Minutes, Hours, Day, Month, Year

With the introduction of a hardware clock the method of setting the clock has changed.

Choose a date/time in the future using perhaps your computer clock or a GPS as the standard. For example if the current date is 5 September 2009 and the current time is 15:43:10, choose 15:45:00 which gives you about two minutes to perform the time/date setting.

Bring up the Menu and using the Up switch move through to 'Year' at item 6 and change if necessary with the left/right buttons. Use the down button to go back to 'Month' at item 5 and again change if necessary. Work your back through the items changing where necessary to the future date/time chosen above. Once the seconds are set to the future time, stay in menu item 1 (seconds) and watch your external clock. When it indicates the future time (15:45:00 in our example) click the down switch. The time will now be saved to the hardware clock and be accurately set. You will be advised that the memory has been updated.

The clock may alternately be set using a GPS connection, VK3UM's EME Planner or when using the REMOTE interface.

(7) Brake/Limit – a stop must be set and affects motor direction and 'limit stops'

Options are:

1. No brake, north stop
2. Brake, north stop
3. No brake, south stop
4. Brake, south stop

Generally Southern Hemisphere stations will use a south stop for EME work. See later for a description of the Brake function.

(8) AZ/EL mode

The options cycle through in the following order with azimuth first:

```
In=None      (No serial encoder or potentiometer attached)
In=Pot/None  (Potentiometer on azimuth and nothing on elevation)
In=None/Pot  (Nothing on azimuth and a potentiometer on elevation)
In=Pot/Pot   (etc)
In=Serial/None
In=Serial/Pot
In=None/Serial
In=Pot/Serial    (Pot on azimuth, serial AZ/EL unit on Elevation)
In=Serial/Serial (Serial AZ/EL unit on both ports - default)
```

These labels identify the value of a variable in the background and non permissible numeric combinations of 4,6,8,9,12,13,14 are shown as [In=?/?](#)

(9) Delay

Delay in seconds before swapping directions to protect the antenna mechanisms. Default is 2 seconds.

(10,11) AZ (and El) spread

Usable for any input device, it is the number of degrees covered by the maximum coverage of any input device. These two menu items enable scaling. Generally there is no point in scaling serial input devices unless you have gearing at the antenna to change the coverage of the encoder.

The value supports fractions of a degree to allow accurate adjustment. Remember that when in the menu system placing the calibrate switch ON will allow increases of whole numbers when adjusting decimal values. With the calibrate switch off small changes may be made. Increasing the number increases the spread. Clearly the number to be used depends on the gearing. Experiment to find the correct value.
Both AZ and EL default settings are 360.00 .

This function enables greater accuracy to be obtained from your encoder data by suitable gearing of the encoding device. For example an AS5045 geared up 4:1 at the antenna with EL spread set to 9 (i.e. 90 degrees), would provide an accuracy better than 0.1 degree but a maximum range of antenna movement of 90 degrees.

(12) Azimuth Offset

This menu item (12) allows the range of any azimuth input system to begin at or above zero. This item works in conjunction with menu items (10 and 29). Because moon and sun calculations only cover from 0-359.999 antenna readings are normalized to this same range and cannot be <0 or >360. Default 0 degrees.

(13) Elevation Offset

As for menu item (12). It may be used to set negative (below horizon) degrees for any input system. For example with a potentiometer you may choose to set Elevation Spread (see above) to 100 degrees, set Elevation Offset to 10 degrees and Menu item (30) to ‘Sub EL offset’ to provide a cover of -10, -9, .. 0,1,2...90.

For auto tracking reasons it is critical that you set software stops to avoid damage with your beam rotating beyond set bounds. Default is 10 degrees and with ‘direction of EL offset’ set to subtract you would establish a lower limit of -10 degrees for your readout.

(14,15) Azimuth/Elevation hysteresis

The mechanical realities of moving antennas require hysteresis to be built into the system to avoid hunting in auto tracking mode. Numbers in this item represent 0.1 degree increments so a value of 10 will cause the motor to switch off when it reaches the computed position. The system will not move the antenna again in auto mode until the tracked object moves outside the value set for hysteresis. Default is 10 = 1 degree. If RunOn menu items 39,40 are set to 0.0 the motors switch off when the antenna reaches the AZ or EL of the object and then remain off until the antenna or the object move outside the hysteresis limits set in items 14,15.

(16,17) Azimuth High Stop/Azimuth Low Stop – software limit switches

Note that azimuth and elevation behave differently. Azimuth stores half values in the eedata of the PIC, while elevation stores true values. Together, “Azimuth High Stop and “Azimuth Low Stop” work together to determine the sector that allows automatic or manual movement both ways.

North stop rotators (menu 7): the two stops allow movement within and back into the sector defined by Low through to High Stops, that is, not through north. Movement out of the area is stopped.

South stop rotators (menu 7): the two stops allow movement within and back into the sector that does not go through south. Movement out of the area is stopped.

Through selection of Limit (menu 7) and these two stops any combination can be selected. You may need to experiment a little.

Low stop must be the lower of the two values.

Because the information is stored in a byte (0-255) each unit represents 2 degrees. To stop the antenna going beyond 180 degrees you must enter half of this value i.e. 90. If the moon or sun is outside the permitted range, the LED (if installed on SW3) will light and motor actions to move further are prevented. Motor movement to shift the antenna into safe territory is permitted. A value of 255 disables this function.

(18) Elevation High Stop – a software limit switch

This is the setting above which the automatic and manual switching will not allow movement in the elevation direction. It is a software implementation of a limit switch at the antenna.

Because the information is stored in a byte (0-255) each unit represents 1 degree. To stop the antenna going above 70 degrees you must enter a value of 70. If the moon or sun is inside the forbidden range, the LED (if installed on SW3) will light and motor actions further into that range are prevented. A value of 255 disables the function.

(19) Elevation Low Stop – a software limit switch

This is the setting below which the automatic and manual switching will not allow movement in a disallowed elevation direction. It is a software implementation of a limit switch at the antenna. Each unit represents 1 degree. The item in memory is stored as a real number so can go below or above zero and unlike the other stops a fractional value can be entered. If the moon or sun is inside the forbidden range, the LED (if installed on SW3) will light and motor actions further into the forbidden area are prevented. A value ≥ 91.00 disables the function.

Default 91.00

When setting this in the menu, remember that switching ‘calibrate’ ON will speed your edit by changing readings in whole degrees.

(20) Height above sea level

In metres, used by the sun and moon routines. Default = 10.0 metres.

(21) Longitude in degrees for home location

Use positive for degrees east of Greenwich, negative for west. Once in this menu item, putting the Calibrate switch into the “Calibrate” position increments and decrements in units rather than 0.1 (10* faster). Default is VK5DJ’s QTH. Don’t forget to return the Calibrate switch to its normal position before leaving the menu or you’ll recalibrate your system.

(22) Latitude in degrees for home location

Negative for south, positive for north. Once in this menu item, closing the Calibrate switch increments and decrements in units rather than 0.1 (10* faster). Default is VK5DJ’s QTH.

(23,24) Park Az and El

The parking positions for the antenna. The ‘Park’ menu item parks the antenna to this position when in ‘Auto’ mode. Default = 0.0 degrees.

(25) AZ resolution 10 bit, 12 bit, 14 bit, 16 bit and SCA61T inclinometer

Since adding facility for 14 and 16 bit encoders it has been necessary to change the display method. Options are:

1. 10 bit

2. 12 bit
3. 14 bit
4. 16 bit
5. SCA61T mode

The LCD reading cycles through the available options. The item affects the maths calculating the conversion of the numbers from the serial AZ/EL unit or from the A/D Converter in the PIC.

This setting is ignored when “AZ/EL Mode” is set for **pot input** in which case it will use 10 bit as this is the resolution of the A/D converter. Default = 12 bit.

(26) EL resolution 10 bit, 12 bit, 14 bit, 16 bit, SCA61T

Elevation resolution - see the previous explanation substituting ‘EL’ for ‘AZ’

Default = 10 bit. The option SCA61T correctly interprets the numbers coming from the AZ/EL board using an SCA61T inclinometer chip.

(27) SCA61T Calibrate

The default value is 124. This equates to 1024 as 900 is added internally to derive the correct offset for calculations. The value may be changed using the left and right arrow keys. The data sheet suggests the use of 1024 but in the device I used it was found that a better offset was 1035 (135 in the menu). It seems that individual devices vary so I included this item to allow fine adjustment. My website provides further information regarding calibration but effectively it involves pointing the arrow of the sensor up and checking for a reading of 90 degrees. If the device reads +90 degrees before vertical and it then flips to -89 then you need to increase this calibration number. If on the other hand you cannot reach +90 degrees at any point then you need to decrease it. The SCA61T is very inaccurate as it approaches 90 degrees. See my website for using elevation offset (menu item 12 and 30) to add 45 degrees and use the most accurate part of the SCA61T curve from -45 to +45 degrees by putting the sensor on a 45 degree slope inside the antenna box or sloping the box itself.

(28) Encoder Averaging - Static

Both the shack unit and the AZ/EL units on the tower do some averaging. The AZ/EL unit does it in between polls: in addition, when an AS5045 is used, there is some built in averaging within the chip. All this serves to reduce flicker and provide improved readout definition.

The shack unit averages readings over the number of cycles set in this item (28) when the beam is *not being moved*. Note that a value of 1 equates to NO averaging. A value of two would average over two inputs and so on. A value of 15 would equate to 15 cycles and provides a substantially improved readout when using an AS5040 and simulates 0.1 degree readouts. (Note: I didn't say ‘accuracy’). The menu system enables the shack unit's averaging process to be disabled using a value of 0 or 1. Most users will leave averaging ON as it will help overcome flicker caused by minor flexing of the antenna system.

(29) Encoder averaging - Moving

When the antenna is moving the same degree of averaging as in menu Item 28 cannot be used as there would be too large a lag.

This item allows a smaller average to be determined during movement (or more correctly when the PIC is actuating movement either by operation of the front panel switches or by automatic operation). I find that a value of 2 is an improvement without causing undue lag. A value of 0 or 1 equates to NO averaging.

(30) Direction of AZ offset

This menu item makes it possible to either add or subtract the offset in menu item (12).

Most antenna pointing requirements can be met by judicious arrangement of 'spread', 'offset' and 'direction of offset'. Experimentation is the best solution. If you have a non geared serial system leave the AZ and EL spread settings at 36 (360 degrees), if not, set 'spread' for the total number of degrees needed, then decide if you want zero start, or above zero start. 'Offset' gives the number of degrees above zero start. Direction (menu 30) determines if the readout is increased or decreased by the offset in (12). There are no negative readouts permitted in azimuth – all readings are corrected to 0-360 degrees. Over-run from 357,358,359...0,1,2 or reverse is only permitted in a 'south system' while 178,179,180...181,182 or reverse is only permitted in a 'north system'.

(31) Direction of EL offset (voltage sources using A/D only)

As per (30) but worked in conjunction with menu items (11) and (13) for elevation control. For example, if a pot is attached to an input and the spread set for 100 degrees, an offset of ≥ 10 degrees, and 'Sub EL offset' (in this menu) then the pot will provide readings from -10 degrees to +90 degrees. Alternately, if the 'Add EL offset' is set then the pot will read from 10 degrees to 110 degrees. This function is very helpful when using a SCA61T and sloping the device by about 45 degrees to use the most accurate part of the conversion curve.

Note that for Elevation Low Stop to work below the horizon this item, menu 30, must be setup to allow negative movement of at least the value in 'Elevation Lostop'.

(32) VGA ON/OFF

This feature has been added to provide an output for use with a secondary project using the Dontronics Micro uVGA-640 board.

<http://www.dontronics-shop.com/product.php?productid=16145&cat=262&page=1>

This feature allows the beam indicator project to display AZ, EL, Moon/Sun position in large numerals to a VGA monitor thus avoiding a computer. The website has details. If you're not using this feature turn it off (Default OFF).

(33) Time ON/OFF

When the unit is in 'External mode' (front panel switch off), you can choose to show the incoming AZ/EL information for the object being tracked or view the time.

For the 4*40 LCD display version this menu item becomes the UTC offset from local in decimal hours * 10. For example 90 = + 9.0 hours, 95=+9.50 hours. For those East of the Dateline you will need to do some simple arithmetic. For example if you are 10 hours behind UTC you will subtract your hours from 24, multiply by 10 and enter 140. E.g. Hawaii is UTC -10 hours, therefore $24-10 = 14$. You would enter 140 in the time offset. The local time will read correctly. The local date is not used in any way so is not computed.

(34) CTS

Used to change the sense of the CTS signal, this setting is almost redundant as I have chosen to use software interrupts to trigger the reception and sending of data in my REMOTE software. However some third party software may require CTS. So for the moment this switch remains. Mostly this menu item will not be used and can be left at default.

Some computers may not interface well to a CTS signal at 0-5V (TTL) levels, one of the reasons I chose to ignore it in my software. As designed, the shack unit uses a MAX232 to convert **data** levels between TTL and RS232 levels (+/-10V or thereabouts) but the CTS line is not channeled through the MAX232. As a result the CTS has 0-5V levels only, unless you install the second MAX232.

The latest version of VK3UM's EME tracking program, or my Remote program for use with Orbitron for satellite work, does not require CTS. If you are using other third party software you MAY find that your computer does not respond to 0-5V on the CTS line. If this happens you will need to cut two traces near J1 and run 4 jumpers around the MAX232. See later section on "**Interfacing to a computer**".

This (34) command defaults to TTL levels but if you choose to make the change to RS232 levels for CTS computer interfacing then you will need to change this to: "**CTS RS232 level**" rather than the default "**CTS set for +5V**". This command inverts the CTS lines to counteract the inversion in the MAX232.

(35) Input Device (In=Normal, In=SEI, In=Yaesu232)

This item allows use of different input devices.

Normal accesses the standard devices

- (a) Analogue inputs on AZ and/or EL sockets
- (b) AZ/EL board which plugs into the AZ and/or EL sockets which may be connected to HH05/12, MA3-P12, SCA61T, other encoders

SEI accesses the SEI interface by US-Digital to match the AD2-B interface with encoders A2 and A2T. The SEI interface must be plugged into the Elevation DB9 socket. Use of the SEI interface also involves some rewiring of the elevation DB9. See the separate 'Optical' page on my website for the manual with details. When set this item accesses both the A2 and A2T encoders through the SEI interface by sequentially polling the elevation port. In this mode the azimuth port is unused. AZ/EL mode (item 8) should be set to Serial/Serial. A second MAX232 is required.

Yaesu accesses the Yaesu GS232A computer interface. The Elevation DB9 must be rewired to this: Pin 3 of J3 to pin 2 of the elevation DB9, Pin 4 of J3 to Pin 3 of elevation DB9, Pin 6 of J3 to Pin 5 of the elevation DB9. Note that the Azimuth port is unused. Communication is at 9600baud, N, 8, 1.

Note that the GS232A is **not** needed to use the Yaesu G5500 satellite AZ/EL rotator with this project. The standard controller on the Yaesu outputs a variable voltage (adjustable) which will interface directly to the "Shack Unit" making use of the A/D converters available on pin 8 of the DB9s and setting the input device on menu item 8 to Pot/Pot. Some adjustment of items 10-13 may be needed to cover the range. The adjustment on the Yaesu controller should be set to achieve 0-5V range if possible, otherwise as high as it will get towards 5V will work fine – you will need to adjust the spread item in menu 10,11 to achieve the full coverage range. Set menu item 35 to "Normal" if you use the G5500 controller without the GS232A. The controller relays will need to be wired appropriately to the G5500 controller motor controls.

The system should work without a GS232A for the **G-800DXA/G-1000DXA/G-2800DXA** Azimuth Rotator, **G-800DXC/G-1000DXC/G-2800DXC** Azimuth Rotator, **G-400** Azimuth

Rotator, **G-500A/G-550** Elevation Rotator, **G-5400B/G-5600B/G-5500**AZ-EL Rotator. You will need to determine the connections for each.

(36) Refraction ON/OFF

There is some discussion on whether refraction should be taken into account in the positions of the sun and moon for radio work. The shack unit program now allows you to choose. The default is ON. When refraction is ON the refraction calculation is NOT taken into account when the moon's true position is below the horizon by more than 5 deg. I have assumed an atmospheric pressure of 1000 mBar and a temperature of 20 degrees C. Clearly this is an approximation but is the only practical solution.

(37) Relay mode

From Version 5.90 a choice of relay mode is provided. Mode A is the original mode where two relays work in tandem for azimuth and another two relays work in tandem for elevation. In mode A one of the relays exchanges the connections on the motor while the second relay switches the power on a short time later. In mode B each relay controls a separate direction. This second method is probably the most common although the first method is less likely to result in a short circuit due to the make and release time of relays. Both methods work well, both require 4 relays. The wiring circuits are shown in Appendix 2. Note that the original PCB caters only for mode A LEDs. See the appendix for relay wiring details including a modification of the LED wiring to cater for Mode B. Note a bug in Mode B was fixed in version 7.00 where entry to the menu mode allowed a relay to remain on.

(38) Doppler

This item enables display of Doppler shift for the frequency chosen. If Doppler frequency is set to anything other than "Doppler Off" and providing the moon is above the horizon, a Doppler reading will appear on line 2 of the display every five seconds for one second.

A calculation of Doppler is made based on the rotation of the earth for your latitude and a calculation that takes into account the velocity of the moon as it moves between apogee and perigee. The display is for Home/Home Doppler shift in Hz.

(39) RunOn mode azimuth

Most systems have some run on affect once the motors cut and the antenna comes to rest. The auto function normally switches a motor off when it reaches the object's AZ and then stays there until the antenna or object move outside the hysteresis limits set in items 14. The RunOn feature enables the auto function to turn a motor off before it reaches the object's AZ and then coast to the object's AZ. This will need to be set experimentally and the value will depend on the mechanical construction of your antenna rotator and on the accuracy of your AZ encoder system.

Important: the value set in RunOn must NOT exceed the value of the hysteresis set in item 14. So if you have hysteresis of 0.5 degrees then RunOn must be ≤ 0.5 degrees.

(40) RunOn mode elevation

As per item 39 but for the Elevation system. This must be set in conjunction with item 15 (hysteresis elevation). **Important:** the value set in RunOn for Elevation must NOT exceed the value of the hysteresis set in item 15. So if you have hysteresis of 0.5 degrees elevation then RunOn must be ≤ 0.5 degrees.

(41) Park mode

From Version 7.0 the Park has moved from a switch to a menu item. This enables the old Park switch to be used for menu selection. It is most easily accessed by accessing the menu with the menu switch, then pressing the 'Down Switch' once. Use the left or right switches to change the setting. When Park is ON it effectively sets the Moon's or Sun's AZ and EL to the setting in your park menu (see item 23,24). If the Auto/Manual switch is moved to the Auto position the beam moves to the Park position and after 5 seconds the brake (if installed) is set.

(42) Checksum

In versions 8.40, 9.51 and 10.00 a checksum option has been added to the computer interface. This was introduced primarily to support the internet mode provided by my program "Remote.exe" and Doug VK3UM's AutoTrack. My "Remote" program provides an interface to Orbitron, or a computer generated moon position (using vk5dj_sunmoon.dll). This interface may operate either through the normal RS232 port of a computer, through an Ethernet cable connected to a WIZ100SR (ethernet to serial interface), or through the internet from a remote location courtesy of the WIZ100SR and "Remote.exe". Choosing "Check ON" accesses an input string from the computer which contains a checksum. If "Check OFF" the shack unit utilizes the old input string method without a checksum. The checksum ensures only good data gets to the shack unit from external sources and is the preferred setting. Some software from other sources may not support the checksum mode. This will reveal itself as slow or nonexistent communication with the computer.

Choice of components

The interfaces use DB25 (computer I/O J1), DB9 (Azimuth J2), DB9 (elevation J3), chosen to avoid accidental confusion of sockets. The LCD is a HD44780 compatible, character based LCD. I used a two line backlit device purchased on VK-Ham, manufactured by Plotech 194V-0. Most are 14 or 16 pin devices. Rockby electronics often have suitable displays. I suggest the following sites for further information regarding 2line 16 character LCDs.

<http://home.iae.nl/users/pouweha/lcd/lcd.shtml>

http://www.repairfaq.org/filipg/LINK/F_Tech_LCD.html

Sources of 4 line by 40 character LCDs are available from

(1) HDM40416L from <http://www.futurlec.com>

(2) <http://www.lcdmodkit.com/lcd/LKC-4004-A2.html>

See Appendix 3 for information on connecting a 4 line display using Version 9.51.

The rear box photo shows the 8 connectors for rotator power/ground and motor leads. Two are unused and were a 'just in case' for the prototype. By mounting the connector strip on a small L shaped bracket I was able to provide a convenient feedthrough from the inside and solid connections for the motor leads.

You may choose to put fuse holders for the motor power and for the main 12V power supply. Next time, I probably will. Not shown in the circuit diagram is a diode wired in series between the +12V and the switch to guard against accidental reversal of power.

The prototype's front panel direction switches are spring loaded SPST push buttons. All other switches need only be SPST.

The choice of a 16F628 or a 16F628A in the AZ/EL board doesn't matter; just remember that the programmer for the PIC must be set accordingly as the two varieties use slightly different programmer timings. 16F648A also work. The crystals in all cases determine critical timings, no substitution of frequency is allowed.

General construction

I have a stock of boards. Check my website for details. All boards are double sided, plated through holes, silk screened design. Someone else might like to convert this to a single sided design if they have the 'knowhow' and the time. The project design is copyright and no portion may be commercially manufactured without my permission.

The photos illustrate major construction methods but there is nothing very critical in layout terms. Just use sound amateur design, avoid overheating components and socket your chips. Note that if required the encoder board and AZ/EL board will fasten together in piggy back fashion providing appropriate connectors and standoffs are used. The connector if used mounts on the back of the encoder board.

Depending on the LCD choice you may need to run the backlight from +12V via a resistor R14, adjust for best results around 100 ohms. Some backlit LCDs have resistors on board that enable 5 volt operation from the normal +5V to the unit, in which case omit R14. Use J8 if the backlight needs +5V on pins 15/16. If you choose to run the backlight from the +5V voltage regulator you will need to heat sink the LM7805 or even mount it externally. If necessary, adjust your LCD connections to match those in the circuit diagram (See Appendix 3 at the end of this document)

For wiring the DS1307 battery backed hardware clock see Appendix 5 at the end of this document. In this case do NOT install the 32768Hz crystal and its bypass caps.

All switches are active when earthed so a common earth lead can be run to these. The active sides of S1, S2 on the board are nearest the LCD plug. The active side of S3 is away from RV1. **DO NOT use the second S3 pin nearest RV1 for the calibrate switch**, it mistakenly goes to +5V instead of 0V, take the S3 earth from another switch. If you would like an indicator when the moon or sun is outside the movement limits of your system, the software is set up to lower S3 in this circumstance. See below how to wire this feature.

Relay 4 is the power switching relay for Up/Down while **relay one** is the direction relay for Up/Down

Relay 2 is the power switching relay for Left/Right and **relay three** is the direction relay for Left/Right

Relay 5 is the brake relay

LEDs

L1 LED indicates down (cathode nearest board corner)

L2 LED indicates up (anode nearest board corner)

L3 LED indicates left (anode nearest board corner)

L4 LED indicates right (cathode nearest board corner)

L5 LED if added indicates moon or sun is outside software limits of antenna.

L5 LED is on the Rev8 circuit diagram shown as external components. This LED can be optionally added to the connector for SW3. The anode of the LED should be connected to the point nearest the corner of connector S3– this is +5V. A 1K ohm resistor can be wired between the cathode of the LED and the SW3 connection on S3. Connect a series resistor of 270 ohms between the active of the calibrate switch and S3. This is a precaution in the unlikely event of a software glitch being shorted to earth by SW3. If an attempt to drive the system below a software limit switch, this LED will light.

For best calibration the calibrate switch should be used in manual operation mode.

The Max232 (IC3) is mandatory. However the second Max232 (IC4) was designed into the board but is normally only required for the **SEI interface**. It has been found that 9600 baud works quite well over 100 metres of Cat 5 cable to the antenna units but in the unlikely event there are problems, there is provision to use -10V to +10V levels by installing the second Max232 chip. Note that if the chip is used with the AZ/EL boards, it will be necessary to create another board at the antenna unit for a matching Max232. Probably one board could service both AZ and EL sender units as the Max232 is a dual channel device. The Max232 chips must always work in pairs or the data direction will be inverted and communication will not be possible.

Most users will **not install IC4 and should therefore install two bridges** joining pins 12/13 of IC4 and pins 8/9 of IC4. Capacitors C12, C13, C14, and C15 should be omitted.

Note the Appendix 2 for wiring the relays and the associated LEDs. Note that if mode B of the relays selection is used then the board connections for LEDs must be ignored and the LEDs connected as per the instructions in Appendix 2.

Adjusting the encoder unit and magnet distances (using AS5040/5045)

The encoder board has a small hole in the centre of the board. Before soldering the AS5040/45 into position, the location of the encoder board may be determined initially by sighting through the hole to a centre mark on the magnet. This hole is also at the physical centre of the board as referenced to the 4 mounting holes. Once the board has been centred using the sighting hole, the mounting holes can be marked and drilled slightly oversize to allow for some final adjustment.

When the unit is complete and power applied, the distance between the AS5040 and the magnet should be adjusted in the centre of the range where both LEDs L3 and L4 are ON, in my case a distance of about 1.5 to 2.0mm. If L3 is off and L4 on, the magnet is moving away from the chip, if L3 is on and L4 is off, the magnet is moving towards the chip. If both LEDs are OFF the magnetic flux is outside tolerance.

Once the AZ/EL unit is plugged into the Azimuth DB9 on the shack unit and providing a reading, put SW3 into the ON position and rotate the magnet. It should be possible to adjust the position of the AS5040 by moving the board to a point where the maximum difference in the readings is 30 or better. This indicates optimum positioning. LEDs 3 and 4 will also light for 360 degrees at this point. If you cannot achieve the less than 30 difference just make it as good as you can. There seems to be a reasonable tolerance to misalignment but there will be some nonlinearity across the 360 degree rotation.

Programming the PICs

The HEX files are available from my website <http://vk5dj.mountgambier.org>

I used WinPic as the programming software and a P16Pro40 programmer until recently. I have now changed to a PICkit3 and I find this works very well. If you use Winpic sure you have the latest version and have parameters for the PIC18F4682 or PIC18F4685 created in the Devices.ini file.

I have a copy of the Devices.ini with a working version for the 18F4682 and 18F4685 if you want me to email it to you.

Initial test setup

Step 1:

Initially install two 10K pots (ideally linear but for the test it doesn't matter) on flying leads to DB9 plugs for the azimuth and elevation ports. Pin 4 (+5V) and 5 (Earth) to the outer connections of the pot and Pin 8 to the wiper.

Step 2:

Operate the "Menu" switch. You are now in the configuration menu.

Step 3:

Use the 'Up' or 'Down' buttons to locate the item 'AZ/EL mode'. Use the 'Right' or 'Left' button to increase or decrease the value to 3. Press the 'Up' button and a message 'Memory updated' appears, you may now reset the auto/manual switch to the manual position to exit the menu system.

Step 4:

Adjustment of the pots will result in changed readings on the LCD.

Step 5:

If you have an AS5040/45 unit ready you could repeat steps (1), (2) and (3) but this time set AZ/EL mode to 7. Make sure the resolution settings in the menu (items 10,11) are set to suit your device. Now plug the serial device into the azimuth port and again you should have readout, but this time azimuth will be driven by the AS5040/45 system and elevation by the potentiometer.

If you are using a rotator and a pre-existing resistive element some experimentation will be necessary to find the right solution. E.g. If your rotator uses a rheostat rather than a potentiometer you will need to convert it to the latter by earthing the open end, alternatively install a potentiometer.

Socket connections (SEI uses only J1 and J3 and uses different connections for J3, see the separate SEI document)

Pin of J1	Pin of DB25 to computer
1 9600 baud IN from comp	2
2 9600 baud OUT to comp	3
3 not used usually or CTS	
4 second enable pin of 4*40 LCD	
5 Earth	7

Pin of J2 (Azimuth) and J3 (Elevation)	Pin of AZ DB9 and EL DB9
1 +12V to antenna unit VR	1
2 Handshake out to ant unit	7
3 9600 baud data IN	3
4 Wiper of pot in	8 if used
5 +5V to top of pot	4 if used
6 Earth	5

J6 switches (earth to activate)

- 1 manual/auto operation (near pin 26 of PIC)
- 2 right direction
- 3 left direction
- 4 up direction
- 5 down direction
- 6 menu
- 7 earth (near pin 32 of PIC)

S1 Moon off/Sun on

S2 Calculations internal on/external off

S3 Calibrate function, momentary action sets encoder to the current sun/moon position. Values saved to memory. On for >3 secs clears offset.

J8 5 volt back light for LCD

LCDs vary considerably in their contrast and backlight connections. Some LCD units require the contrast control to be earthed for correct contrast (they might even appear blank if not at 0V) while others require the potentiometer RV1 to be adjusted to a critical position. Many LCDs have a separate set of connections for the LEDs (usually pins 15,16) but often no connection is required because an internal system supplies the backlight voltage from the +5V input on pin2. When connecting LCDs with backlights, firstly omit jumper 8 and R14 until you observe whether the backlight is active.

If no backlight is observed check your specification sheet if possible. Otherwise try either jumper 8 to provide 5V or use R14 to +12V.

Omit jumper if running from +12V via R14 or bad things will happen when 12 V appears on the 5V regulated line.

A word on accuracy

Tracking programs for the moon involve many variables and are quite complex, there are for example over fifty orbital corrections considered in calculating the longitude of the moon and a similar number for the right ascension. Don't expect a guaranteed accuracy much better than +/-0.2 degree for the moon from most programs, including the one in this project. The number of digits displayed after the decimal place by a program is often no indication of accuracy. I use AA.EXE as my standard for checking moon/sun calculations – it is available from <http://www.moshier.net/aadoc.html> and claims an accuracy of 0.5 arc second as checked against the Astronomical Almanac. AA corrects for light refraction if the object is

higher than 1 degree below the horizon. The program in the 'shack unit' may be enabled to correct for refraction above -5 deg EL and assumes 20 deg C and 1013mB pressure.

The position of the sun is relatively easily calculated and the sun program in this project is accurate to better than 0.1 degree so use it for the alignment of antennas.

Encoders whether magnetic or optical all have errors and are susceptible to temperature and/or transition point issues. The topic of measurements and mechanical limitations of pointing large antenna systems warrants another article in itself. This project won't put Parkes (a large Australian radio telescope) in your backyard but hopefully will aid many in improving their tracking to better than 0.5 degree at reasonable cost.

Default settings in the supplied HEX file – a guide only, some may change

Seconds: 0
Minutes: 12
Hours: 12
Day: 15
Month: 6
Year: 2008
Brake: none, north stop
AZ/EL modes: serial AZ and EL
Delay before opposite switch: 2 secs
Azimuth pot spread: 360.00 (equates to 360 degrees)
Elevation pot spread: 360.00 (equates to 360 degrees)
AZ offset: 0
EL offset: 10
AZ hysteresis: 10 – each unit represents 0.1 degree
EL hysteresis: 10 – each unit represents 0.1 degree
AZ software stop high: 255 –each unit represents 2 degrees (255 = no stop)
AZ software stop low: 255 –each unit represents 2 degrees (255 = no stop)
EL software stop high: 255 –each unit represents 1 degrees (255 = no stop)
EL software stop low: 255 –each unit represents 1 degrees (>=91.0 = no stop)
Ht in metres: 10
Longitude: 140.35 (+ represents west)
Latitude: -37.58 (- represents south)
Park AZ: 1.0 in degrees
Park EL: 0 in degrees
AZ 10 bit resolution
EL 10 bit resolution
SCA61T cal: 124
Averaging stationary = 16
Averaging moving = 1
Sub AZ offset
Sub EL offset
VGA off
Time off in External mode (show AZ/EL on lower line of display)
TTL levels +5V for CTS
In=Normal
Refraction ON
Relay mode A
Doppler off
RunOnAZ 0.0
RunOnEL 0.0
Park OFF
Check OFF

Using the Calibrate Function

The calibrate switch works over a wide range and is setup as follows.

Align the antenna system to the noise from the moon or the sun as best you can and then make mechanical adjustments so that the antenna sensors read as close as practical to the calculated moon or sun readout on the second line of the screen.

Press the calibrate switch for a moment (<1 second). The system is now calibrated and you will see that the encoder readings match the calculated position. The offset values are stored in permanent memory. If you wish to clear the memory hold the calibrate switch down for at least 3 seconds and the offset will be removed and you will see the true readout on the top line.

Remember that the Calibrate switch has a dual role, when in menu mode it causes some items to update at 10* the speed. Ensure the calibrate switch is off before exiting the menu system

Interfacing to a computer

Interfacing can be a problem primarily because of the RS232 levels provided or expected by a computer serial port.

This project uses 9600 baud, 8 data bits, 1 stop bit and no parity for all communication to the antenna units and the computer

Here are some scenarios:

Scenario 1: You want to use VK3UMs EME Planner or Orbitron for Satellite tracking (Remote.exe)

Because this is the simplest option I suggest you start here.
Do not install the CTS line to the DB25.

Scenario 2: Your computer needs RS232 levels on CTS and you want to use third party software. Wire in the CTS line on pin 4 of J1 to the DB25. Set menu item 34 to CTS +5v.

If this does not work try:

This modification converts the CTS line to work with RS232 levels.

Examine photo “Cut for RS232.jpg”. The two white marks indicate where you should cut the traces going to pins 3 and 4 of J1.

Examine photo “RS232 mod.jpg” and install the 4 jumpers shown in the photo.

Fixing the CTS

- Pin 3 of J1 goes to pin 7 of the MAX232,
- Pin 10 of the MAX232 goes to the other side of the cut trace

Make sure that command (33) is set for “CTS RS232 level”.

Scenario 3: You want to use the VGA option for display

Your shack unit should be set for TTL levels (Command 33) and the CTS from J1 should connect to pin 5 of the DB25 while the DTR line should connect to pin 20 of the DB25.

Interfacing with the VK3UM Autotrack/EME Planner

With version 8.40, 9.51 and 10.0 the auto/manual switch is software controlled by the AutoTrack program. Leave Auto/Manual in the Manual position.

Put the Int/Ext switch in External mode.

When Autotrack boots it sets the shack unit to external mode and does all the controlling from the computer.

Doug's program provides necessary software stops to protect the antenna.

Effectively the VK5DJ shack unit is providing antenna information to Doug's program while Doug's program provides object AZ/EL to the shack unit and switching information to the relays.

The program "Remote" uses a similar strategy but lets you decide whether to automatically or manually control the beam movement or have no control at all in which case the Auto/Manual Switch can be used on the shack unit which causes the shack unit to control things based on the positional data being sent by the computer. See the separate Remote Manual.

Setting the time using the computer

The VK3UM planner updates the time in your shack unit to UTC. It does this automatically whenever the program opens.

Communication between EME Planner and the Shack Unit

Ensure your correct serial port is set with a configuration of 9600,8,1,N. In the event of a communication problem check the com port set up.

Check Doug's software for further operational information, mostly the 'hints' are all that are needed. Doug plans a Help File for the future.

If for some reason the computer locks up and the shack unit is left in EME Planner mode (the * is still showing at the right hand end of the bottom row) you can drop out by switching the shack unit from External mode back to Internal mode. Normally this reset is performed automatically by EME Planner.

Using Orbitron

Orbitron is a very nice satellite tracking program. The author (Sebastian Stoff) has provided external access to many of the program's outputs. I have accessed the azimuth and elevation output and arranged for this to be used to track the antennae using the software and hardware of the shack unit. The interface screen also shows the current location of the antenna.

For setup of the REMOTE interface software read the separate file (Using Orbitron.pdf).

The Orbitron interface has the capacity to update the time in your shack unit to UTC. Click the 'Update time' button to set the clock in the shack unit. All information is drawn internally from the computer including the current UTC offset.

Brake Operation

If a brake is available and it is activated in the menu system then it works in the following manner. When the mode switch is in the 'manual' position the brake is immediately released when a direction switch is activated. Five seconds after the beam comes to a stop the brake is set. In automatic mode the brake works in the same fashion. The Park operation works in the same manner but due to an ambiguity at exactly 0.0 degrees and 180 degrees azimuth, it is better to make the parked position a small rotation from 0.0 or 180.0, for example 1.0 degrees or 181 degrees.

GPS setting of the time, date, latitude and longitude

The system may be set from a GPS attached to the computer port of the shack unit. The data should be on pin 2 of the DB25 and the earth pin 7. Because both the shack unit and the GPS are DCE devices, if you choose to use purchased cables you will need a null modem adapter or cable for the connection between the GPS and the shack unit so that pins 2 and 3 are crossed over.

Currently the software only supports 4800baud, so if your GPS does not provide NMEA data at 4800 baud you will be unable to use this feature.

The NMEA string is anything but standard in all GPS units so I have included some strategies that hopefully work for all NMEA "\$GPRMC" strings.

To use the GPS activate the "UP" button on the shack unit then turn the unit on. Hold the button active for at least 1 second, at which point the button (switch) may be released and the welcome screen will remain on the screen. If the GPS is already on and satellites are found you will see the welcome screen change to a display of the UTC time while the second line will display the latitude and longitude. This display will remain for three seconds before changing to the normal tracking screen. No further readings are taken from the GPS and it may now be turned off or disconnected. The Latitude and Longitude are saved to Eprom memory but the time and date are lost if the power is removed.

Note that if the welcome screen seems to be locked on, it is probably because the satellites are not yet acquired (the program tests for acquisition) or your GPS is not compatible.

The system was tested on my system with a Garmin GPS 12 and a Magellan GPS310.

Due to a shortage of memory the program does not offer a speed change. Most of the better GPS units can change baud rate while the rest seem to use 4800. I know that a number of amateurs have GPS frequency standards available that output at 4800 baud.

Summary

The construction allows various sensors to be used. US Digital manufacture an encoder in a pot style case (MA3-P12) that outputs a PWM signal. I have provided a new HEX file for the AZ/EL unit to allow the use of this encoder. The file is on my website. Another option is the MA2 system from US-Digital that provides a 0-5V variable output that could be used with the 'Potentiometer mode'. A European option, the HH-05 is a AS5040 (10 bit) solution for direct use with the original AZ/EL software, while the HH-12 is an AS5045 (12 bit) solution and works directly with the AS5045 hex file for the AZ/EL unit. As of January 2008 the unit also supports use of US-Digital's A2-B SEI interface for using with the A2/A2T encoders. A recent option is a Gray code system for those who have 16 bit gray coded encoders. I have

written code for the AZ/EL unit to interface to serial gray code out of a simple interface using two 74HC165 chips. See my web site.

I would like to thank Russell Lemke VK3ZQB for his work in turning my pencil drawings into professional looking circuit diagrams yet again and also developing the board layouts. Without him it would not have been the same quality project. Also thanks to Doug VK3UM who has linked the project to his well respected EME tracking software. I am happy to answer any questions via email but firstly please check my website for any documentation updates.

Note that the new package on the website now includes a modified circuit diagram of the shack unit showing the external parts for the out of range LED.

John VK5DJ

Updated 10th June 2010

Appendix 1

Some example settings

(note that SEI connection has less options – see SEI manual)

Scene 1

User has AS5040 on both azimuth and elevation inputs. His antenna can be moved in azimuth from 0 to 360 and his elevation unit from 0-90 degrees and both encoder systems represent 1:1 movement of the antenna (that is there is no gearing to increase the movement of the encoder relative to the movement of the antenna). He has no brake and the rotator stop is South. He wants a 2 sec delay when swapping direction. His beam has little slack and the motors start and stop quickly so hysteresis is small so set for ½ degree. Height, Lat, Long are 123 metres, East 130.34 and South 37.01 His beam parks on its back at 0 deg AZ. He wants averaging on.

Scene 2

User has AS5045 on azimuth (as it is direct drive its range is 360 even if it is not allowed the full travel) and potentiometer on elevation input. His antenna can be moved in azimuth from 95 through 0 to 280 and his elevation unit from -10 to 100 degrees. He can see one degree below horizon. The azimuth encoder is direct coupled and moves in a 1:1 relationship while the potentiometer on elevation is geared to produce 150 degrees from end to end. He has a brake and a south rotator stop. He wants no delay when swapping direction (he's good at welding). His beam has a fair bit of slack and the motors are fast and tend to run on so hysteresis is large and set for 2 degrees. Height, Lat, Long are 3 m, West 130.3 and South 18.0. His beam parks at 0 AZ and 0 EL. He wants averaging on.

Scene 3

This user has an AS5045 on azimuth and a screwjack on the elevation. His antenna has a north stop because he lives in the northern hemisphere and can rotate seamlessly over 360 degrees. Mechanically elevation can go from -5 degrees to 95 degrees with the screwjack and he has set the AZ/EL unit for elevation to a spread of 110 degrees (see screwjack manual). It will therefore be necessary to set the shack unit to spread 110 degrees to match it. His station cannot see below the horizon so wants the elevation to stop at -1 degree. He doesn't have a brake. Hysteresis AZ is 0.8 degree and EL is 0.4. He wants a 1 sec delay before swapping direction. Park is at 180.0 degrees AZ and 0.5 deg EL. Height, Lat, Long are 75 m, West 23.11 and North 32.12. He wants averaging off.

Scene 4

This user is almost surrounded by trees except for a smallish window in the north-east. She has arranged a 6:1 quality gearing system to her azimuth AS5040 decoder to get better accuracy from her AS5040 10 bit decoder. She only needs to cover 60 degrees in azimuth starting at 24 to 84 degrees (must be even numbers).

A 4:1 quality gearing system for her elevation encoder means she covers 90 degrees elevation. She cannot see below the horizon. She has no brake but a north stop. Other issues are already dealt with in other examples so the table shows those relevant to this scenario. Because of her small window a north rotator stop will work even though she is in the southern hemisphere.

Scene 5

This user has two MA-2 (analogue output 0-5V) by US-Digital, one to cover 360 degrees AZ and 120 degrees EL (geared to achieve this by 3:1). The elevation unit may travel from -10 degrees to 110 degrees but the below horizon set to -5 degrees. The rotator is limited at south, no brake. It is probably not wise to put a stop at the real mechanical limit of 110 degrees, so I've set it 1 degree down.

Scene 6

This user has two potentiometers geared to produce 0-5V over a range of 370 degrees in a commercial rotator. We set AZ and EL spreads by entering 37 in each spread. No below horizon tracking required and the elevation doesn't go below zero, North stop with brake.

Scene 7

This user wants to go beyond 360 degrees as his rotator allows 370° travel in Azimuth, 10 degrees beyond 360. This is not possible with the shack software.

Menu	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Description
7	2	3	0	0	2	1	Brake / limit
8	15	7	15	15	3	3	AZ/EL mode
9	2	0	1				Delay
10	36	36	36	6	36	37	AZ spread
11	36	15	11	9	12	37	EL spread
12	0	0	0	0			AZ offset
13	0	10	5	0	10		EL offset
14	5	20	8				AZ hysteresis
15	5	20	4				EL hysteresis
16	255	140	255	42	255	255	AZ high stop
17	255	48	255	12	255	255	AZ low stop
18	255	100	47	0	109	180	EL high stop
19	91.0	-1.0	-1.0	45	-5.0	0	EL low stop
20	123	3	75				Height ASL
21	130.34	-130.3	-23.11				Longitude
22	-37.01	-18.0	32.12				Latitude
23	0	0	180.0				Park AZ
24	90	0	0.50				Park EL
25	10bit	12 bit	12 bit	10bit	10bit		AZ 10 or 12 bit
26	10bit	10 bit	12 bit	10bit	10bit		AZ 10 or 12 bit
27	X	X	X	X	X	X	SCA61T calibration
28	On	on	off				Averaging
29	X	X	X	X	X	X	Direction AZ offset
30	X	subt	subt	X	subt		Direction EL offset

Notes:

- X= don't care
- These are examples developed without full testing, there may be a mistake. Check all operations thoroughly and assume I MAY have an error in the table. Use as a guide. Final settings are your responsibility and thorough testing with the manual switches should be done before putting the unit over to automatic.
- Because the software and the manual progress, there may be small inconsistencies. I try to keep them matched but forgive small slips and send email to me if you want clarifications. Version 4.9 dropped the DegBelHorz menu item and introduced a negative offset.

Appendix 2

Wiring the Relays and the LEDs

When I originally designed the board I opted for a relay system that I thought offered an advantage. I made it harder than it should have been. From Version 5.90, I offer an alternative relay operation through menu item 36.

Original design (Mode A) default and settable in menu 36

A pair of relays run the up/down system, and another pair of relays run the left/right (CCW/CW) system.

My original idea was that one relay determined direction and the other relay turned on the power 50mS later.

The LEDs are wired in a somewhat complex AND gate method. This wiring is available on the board. Follow the original instructions.

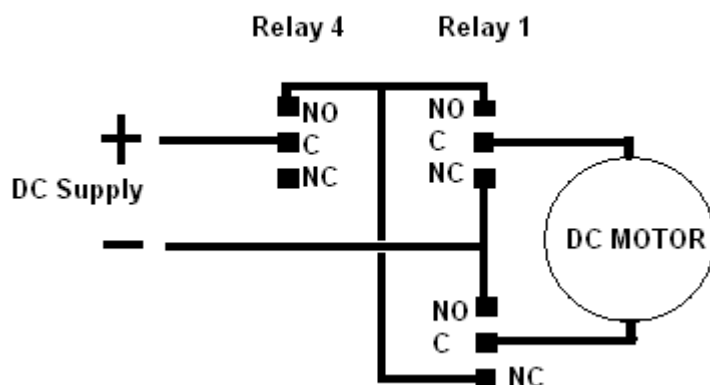
Unfortunately there is also a labelling problem on the board with regard to which relay should be connected so there was some inconsistency. Use the following if you plan to use my original relay switching method use the screen printed information on the top of the board:

Relay 4 is the power switching relay for Up/Down while **relay one** is the direction relay for Up/Down

Relay 2 is the power switching relay for Left/Right and **relay three** is the direction relay for Left/Right

Relay 5 is the brake relay

Relay wiring for original relay scheme:



The left/right (CCW/CW) direction is the same circuit with relays 2 and 3.

New arrangement Mode B (Version 5.90) set via menu 36:

Four relays each represent a direction. Use the screen print information on board.

Relay 1 is UP

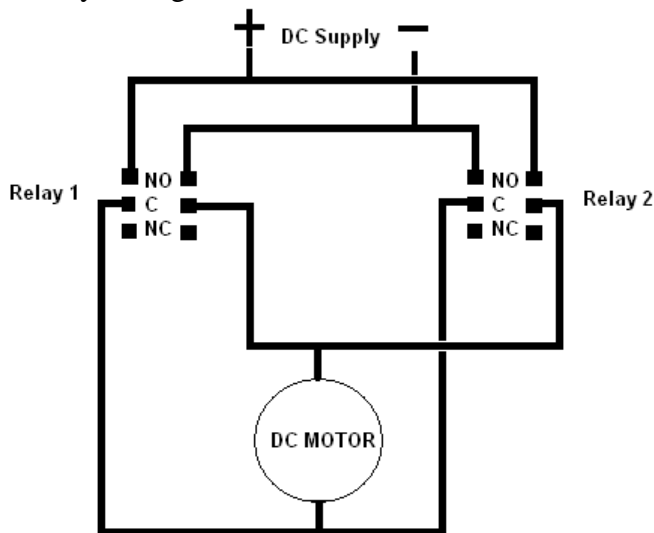
Relay 2 is DOWN

Relay 3 is LEFT or CCW

Relay 4 is RIGHT or CW

Relay 5 is BRAKE

The relay wiring for DC motor control should be:



The LED wiring on the board should be omitted or ignored.

To wire the LEDs for this new circuit disregard the wiring on the main board and instead:

Connect the anode of each LED through a 470 ohm resistor to +12V.

Connect the cathode of each LED to the respective switched relay coil connection. This could be at the relay itself or use the board pins on the main PCB near the driver transistors Q1, Q2, Q3, Q4.

Stan, LZ2STO reports that in ModeB the LEDs are not protected from reverse voltage generated by the relay coil, the solution is to add on each relay another diode, cathode to +12V, anode to collector of transistor.

To speed up the inputs from the antennas when the antenna is moving in Version 9 I have removed an existing delay in ModeB relay operation. Originally the delay was put there to ensure a direction relay had time to switch off before the opposite direction relay fired to avoid short circuits on the output switching to the rotator. The 'Delay' menu item 9 should solve this race problem. Set delay for a minimum of 1 second, preferably two seconds to avoid problems of slow release relays and to give an antenna time to settle mechanically before moving in the reverse direction.

If shorts do occur (and I can't see why that should happen if you use 'Delay') you will need to look at some relay wiring that provides an interlock function.

Appendix 3

Wiring the LCD

Some LCDs have the connections along the bottom and some along the top. This will result in some LCDs following the sequence of the pins on the board and in others it will result in the complete reversal of order.

I have both LCD types. It can be confusing.

I recommend that before you cut the hole in the front panel for the LCD that you wire up the LCD with the bare bones board (see my photo) to check it. The LCD will run with a programmed PIC and no other connections (apart from +12V and Gnd to the board of course). This will prevent the embarrassing mistake of installing the LCD upside down! Yes, I did this once before learning my lesson and having to make another front panel.

LCD connections

For a standard HD44780 2 line display

Pins on main board P1	P1 function
Pin 1 is nearest the contrast pot.	
1	E
2	+5V
3	Contrast pot
4	RS
5	R/W (usually earthed to write)
6	Enable
7	D0 unused
8	D1 unused
9	D2 unused
10	D3 unused
11	D4 (4 bit input from D4-D7)
12	D5
13	D6
14	D7
15	Backlight +ve (usually +5V depends on what the lcd has on board)
16	Backlight -ve (usually earth)

Wire most LCDs

pin 1 of P1 to pin 1 of LCD,
pin 2 of P1 to pin 2 of LCD etc

Wiring a 4 line display with Version 9.51

The four line displays used in this version of the project are really two displays in one. There are two enable pins and the system works by enabling the top two lines, writing the information, then disabling the top display and enabling the bottom two lines then writing the information there. It all works quite well.

You will need to check the data sheet for the display you buy. It must be HD44780 compatible. Locate the two enable pins. The first enable pin goes to the usual pin 6 on P1 of the main board. The second enable pin goes to pin 4 of J1. In the original version this pin 4 was the DTR connection to the computer, this is no longer used for that purpose and has been programmed in the four line LCD version to be a second enable pin.

Appendix 4

Wiring the Hardware Clock

I use the DS1307 board from Futurlec. The board is mounted on one side of the box and active leads from the DS1307 connector to the ports previously used for the 32687Hz crystal. If you have already installed a crystal and bypass capacitors these will need to be removed when using a hardware clock. A shortage of free ports on the PIC required this change.

Look at the photo for details.

I connected the SDA connection on the clock to pin 15 of the PIC (I used the blank hole for the no longer used crystal bypass capacitor).

The SCL lead goes to pin 16 of the PIC (again I used the blank hole for the other capacitor). The GND lead goes to an unused GND connection for the capacitors.

Power to the module

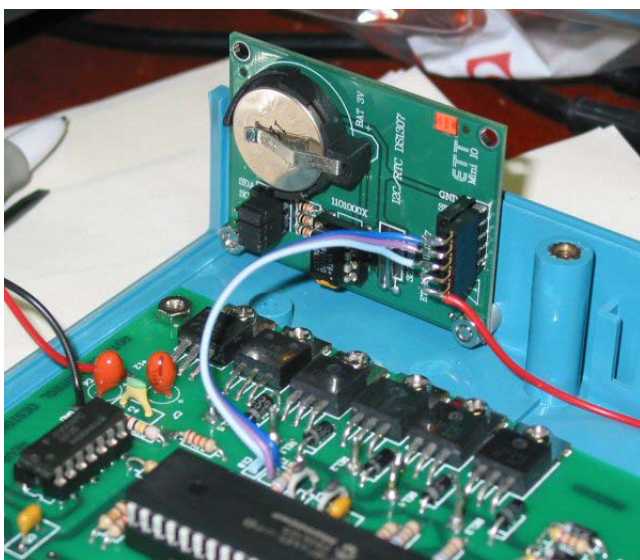
Be careful: when hooking up check that you do have a +5V location for power.

Options:

- (1) If you run your LCD backlight from +5V via J8 then R14 will be missing and a source of +5V is available from the unused hole for R14 near J8. Do NOT use the end near the corner of the board as this has +12V on it.
- (2) If you are not using J8 then the pin of J8 closest to the PIC has +5V on it.
- (3) Alternately use the pin of the 7805 nearest the first TIP31C, this is the +5V out of the regulator.

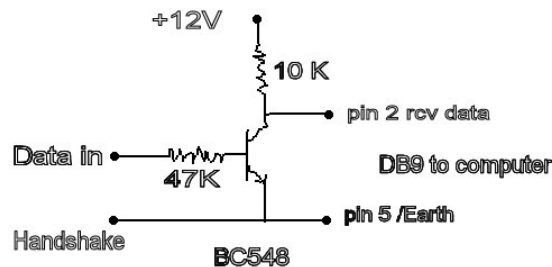
Always check with a multimeter first.

In the absence of +5V the clock runs from its internal battery to keep the correct time.



Appendix 5: Using a computer as a testbed for AZ/EL unit

In the original prototype the AZ/EL unit had an additional transistor used as a data inverter to enable a direct connection to a computer serial port for testing purposes. I omitted this transistor when the final design was made. If you want to test your AZ/EL boards prior to building the main unit (or wish to narrow down a fault condition) it is possible to connect the AZ/EL board to a computer providing that you make a simple inverter (I mount the transistor directly on the DB9, the collector and emitter of the transistor) and connect up two resistors as per the diagram. The resistors just float in midair.



You will also need to put SW2 in the ON position (0V) and ground the handshaking line that normally goes to pin 7 of the DB9.

Note that data in to a computer is on pin 2 of a DB9 whereas the shack unit expects the data on pin 3.

From Version 6.00 of the shack software I have compiled the AZ/EL units to expect a hardwired to 0V handshake line when in the SW2 ON position. If you use an old version of the software you will receive only one line of input to Hyperterm and the display will stop. This is because the old software waited for the handshake line to go high in between data outputs. It is not necessary to update AZ/EL software if you don't plan to make this direct connection to a computer serial port.

Note: Hyperterm should be set to: 9600,8,1,N and no handshaking

Trouble shooting the main PIC (18F4620, 18F4680, 18F4682, 18F4685)

With CRO set to 5msec sweep and 0.2V per division and probe set to 10* (effectively 2V/div) the following is observed on my working unit.

Pin number	Approx freq	Approx voltage of wave
9 (handshake to Elev)	5 / sec with 5 th pulse missing	0 volt pulse from +5V
23 (handshake to Az)	5/ sec with 5 th pulse mssing	0 volt pulse from +5V
13,14 (8MHz xtal)	8MHz	4.8V P to P
15,16 (32 KHz xtal)	32768 Hz	1.8V P to P
19 (switch 4066 Elev)	5 / sec with 5 th pulse missing	+5V pulse
21 (switch 4066 Az)	5 / sec with 5 th pulse missing	+5V pulse
26 (9600 baud data in)	10KHz data	+5V data
36-40 (data to LCD)	High frequency not measured	5V

Handshaking is approximately 5Hz with the 5th pulse missing as the PIC is calculating moon position in this gap.

Appendix 6: Multimeter readings, negative to ground

Pin number	Function	Level
1 MCLR	PIC reset	+5V
2 A/D input	A/D input from pot Elevation	Variable 0-5V with pot
3 A/D input	A/D input from pot Azimuth	Variable 0-5V with pot
4	Motor 3 relay	0V to +5V when active
5	Calibrate switch	Off is +5V
6	External/internal switch	External +5V
7	Motor 2 relay	0 to 5V when active
8	Motor 4 relay	0 to 5V when active
10	DTR (an input from comp)	+5V when inactive
11 Vdd	Power	+5 Volt
12 Vss	power (gnd)	0 Volt
17	Menu switch	5V when off
18	CTS (an output to comp)	0 V computer not used
20	Motor 1 relay	0 to 5V when active
22	Keydata 4066 gate - comp	0 V computer not used
24	Auto/Man switch	0 V on manual
25	Data OUT MAX232	+ 5V computer not used
26	Data IN from 4066	Varying depending on data
27	Switch right	Right off +5V
28	Switch left	Left off +5V
29	Switch up	Up off +5V
30	Switch down	Down off +5V
31 Vss	power (gnd)	0 Volt
32 Vdd	power	+5Volt
33	Brake relay	0 to +5V when active
34	Sun/Moon switch	Sun is 0V, Moon +V
35	Enable LCD	0 V
36	RS pin on LCD	High speed switching

Appendix 7: Using the system with a Yaesu G5500 AZ/EL rotator

With no modification the unit will work with a G5500 by direct connection to the rotator box. No GS232A computer interface is necessary. The rotator controller box (supplied with the rotator) has an 8 pin connector on the rear. It outputs a varying voltage for each of the AZ and EL directions. It is actually the output of an opamp in the controller box and is therefore less likely to cause RF problems. It may or may not be necessary to put chokes or filters on the A/D converter lines (pin 8 of the DB9s).

Use Mode B for the relay wiring and use the appropriate menu item 37 to set Mode B. The LEDs should be wired to run from the relays not the board in Mode B

Connections for a G5500 connected without a GS232A.

Pin	Function	8 pin socket on G5500
8 on AZ DB9	AZ voltage from 'pot'	6 on G5500
8 on EL DB9	EL voltage from 'pot'	1 on G5500
5 on AZ/EL DB9	Ground	8 on G5500
Up relay	Ground this to turn up	5 on G5500
Down relay	Ground this to turn down	3 on G5500
Left relay (CCW)	Ground this to turn left	4 on G5500
Right relay (CW)	Ground this to turn right	2 on G5500

Use menu items 10, 11 to set the appropriate spread to scale the readings from 0-360 for azimuth and 0-180 for elevation.

General Yaesu usage without a GS232A

Note that the GS232A is **not** needed to use the Yaesu G5500 satellite AZ/EL rotator with this project. The standard controller on the Yaesu outputs a variable voltage (adjustable) which will interface directly to the "Shack Unit" making use of the A/D converters available on pin 8 of the DB9s and setting the input device on menu item 8 to Pot/Pot. Some adjustment of items 10-13 may be needed to cover the range. The adjustment on the Yaesu controller should be set to achieve 0-5V range if possible, otherwise as high as it will get towards 5V will work fine – you will need to adjust the spread item in menu 10,11 to achieve the full coverage range. Set menu item 35 to "Normal" if you use the G5500 controller without the GS232A. The controller relays will need to be wired appropriately to the G5500 controller motor controls.

The system should work without a GS232A for the **G-800DXA/G-1000DXA/G-2800DXA** Azimuth Rotator, **G-800DXC/G-1000DXC/G-2800DXC** Azimuth Rotator, **G-400** Azimuth Rotator, **G-500A/G-550** Elevation Rotator, **G-5400B/G-5600B/G-5500AZ-EL** Rotator. You will need to determine the connections for each.

Using a Yaesu GS232A

Yaesu in menu item 35 accesses the Yaesu GS232A computer interface. The Elevation DB9 must be rewired to this: Pin 3 of J3 to pin 2 of the elevation DB9, Pin 4 of J3 to Pin 3 of elevation DB9, Pin 6 of J3 to Pin 5 of the elevation DB9. Note that the Azimuth port is unused. Communication is at 9600baud, N, 8, 1.

If you use GS232A mode you will not need the relays but use ModeB in menu 37 and wire your LEDs with +ve lead to 5V via 470 ohm resistors and the cathode of each LED to the appropriate TIP31C to provide direction indication.

Appendix 8: Things to watch out for

- When using a computer program with the shack unit in external mode and if the program uses an offset from the direction shown by your encoders, ensure that the calibrate function in the shack unit is cancelled (hold down the calibrate switch for 5 seconds or until the ‘Calibrate Off’ message appears).

Generally I recommend not using the offset of the external program but using the ‘Calibrate’ function in the ‘Shack unit, you might like to try both alternatives and make your own decision on this.

- Setting the clock is tricky. I chose to allow update of time only when the seconds are updated. See the information in Menu Items 1-6 for the sequence.
- Make sure you read the manual thoroughly but if you still can’t understand how something works I will answer emails and do my best to help.
- Using ModeB wiring does open up the possibility of shorts across the switching to the motor in some instances. Read the section on wiring the relays carefully and ensure you use the Delay menu item 9 to use at least one second delay.
- If you cannot achieve communication with your computer change the setting of item 34 in the menu. This will probably sort it out. Also check that you have wired the DTR signal to pin 7 of the DB25 rather than pin 20 (see notes under Interfacing to a Computer). Computers do seem to vary with their needs.