HOW THE BETTERRF SCREWDRIVER CONTROL SYSTEM WORKS

J. van Putten, W8QT
The BetterRF Co.

The BetterRF Co. has introduced its 7000 SCREWDRIVER Control System to be used with ICOM's new IC-7000 transceiver. The implementation of the motor control in this system represents a departure from the usual methods employed for linking an accessory to a transceiver. In particular, the 7000 SCREWDRIVER System utilizes the CI-V commands that the IC-7000 understands to capture the front panel controls of the transceiver and redirect them for use by the accessory during the time that the accessory is active. The result is the elimination of the duplicate circuitry, indicators and human interface necessary in the the traditional approach seen in most accessories.

The BetterRF Screwdriver Control System for the ICOM 7000 transceiver consists of two components: one is the 7000 TUNE Control and the other is the 7000 SCREWDRIVER Control. The TUNE Control contains the intelligence of the system while SCREWDRIVER Control responds to commands to control the motor, returns acknowledgements and motor current data. The SCREWDRIVER Control receives the power for its electronics and relays from the TUNE Control. The power supplied through the 13.8 V Power Connector on the SCREWDRIVER Control is used only to run the antenna motor via the relays inside the unit. Besides the motor control relays, the unit also contains a SPDT relay which is activated whenever the system is in the tune or set-up modes. This relay can be used to control an external amplifier or any other device which must be disabled during the tuning or the set up processes. The common connection of this relay floats with respect to ground so it may be used to apply a potential to the contacts, to ground the contacts or to make and break a circuit.

The TUNE Control communicates with the IC-7000 via the CI-V bus and the Molex® antenna tuner port on the transceiver. The latter sends and receives simple on/off signals while the CI-V port enables the TUNE Control to take over the operation of the IC-7000 during the tuning and the set-up processes. Before the TUNE Control takes over the operation of the IC-7000, it first saves the operating conditions which the user has chosen. On completion of the tuning or set-up process, the TUNE Control restores the operating conditions it has saved. In this manner, the user is not inconvenienced by the shift in operating modes and parameters needed to implement the tuning or set-up processes. In fact, the user may not even be aware that the transceiver has been operating in a completely different mode during these processes. All the data generated in the set-up mode is stored in the non-volatile memory of the TUNE Control so it will not be lost even if the power is interrupted.

The CI-V Bus.

The IC-7000 responds to a rich set of commands via the CI-V bus. These commands have grown from a few for early radios to pages of commands for the most recent transceiver models. It is the availability of these commands that allows users to control their rigs from a PC and allows the SCREWDRIVER Control System to implement a sophisticated control procedure. The CI-V bus is a multi-drop bus in that up to seven different devices may be connected in parallel. Every device listens to the bus for a general call or a command containing its unique ID number.

The bus is an open collector bus so that the only thing a device can do is pull the bus line to ground. Commands are a series of eight bits preceded by a start bit (which is logical zero or ground) and followed by a stop bit (a logical one or 5 volts) established by a pull-up resistor somewhere on the bus. The general protocol is a preamble which contains the ID of the device to which the command is to be directed and the ID of the device which will send the command. This is then followed by the command which may be many bytes long and concludes with an End-Of-File. Responses to a command may be data, an acknowledgement of reception, or a failure code. General information on the CI-V commands is included in the user manual for the transceivers. Unfortunately for a someone attempting to utilize some of the commands, not all the parameters required are listed so it is necessary to experiment.

Clearly with multiple devices all possibly talking at the same time, some sort of collision detection must be implemented with a retry procedure. Simple methods include checking that there is a start bit and a stop bit at the expected times and to ascertain that when a device is supposed to be sending a one, the bus is not being pulled low by another device on the bus. Of course, for more critical uses sophisticated procedures are available. The TUNE Control implements collision detection and automatic retrying if collisions or other transmission problems are encountered. In practice, a collision from which it was not possible to recover gracefully has not been observed.

The Command Structure in the 7000 TUNE Control.

Twenty six distinct commands to the IC-7000 have been built into the SCREWDRIVER Control System. These range from simple ones that turn the transceiver on or off to complicated ones that require a large amount of data to be transferred. Each command has a unique index by which it is identified. By employing a multitude of commands, it is possible to combine them in various ways to perform complex tasks.

Whenever the SCREWDRIVER Control System wishes the IC-7000 to perform a particular task, a series of commands is sent out which implements the task to be done. This is accomplished by parsing through the table of command indices that define the particular task. Each command is issued in sequence until the entire task is complete.

The Data Structure of the 7000 TUNE Control.

While it would have possible to implement each task and each command with computer code unique to that task, the amount of program storage would have far exceeded that capacity of the micro-controller that had been selected for the hardware implementation. Therefore, it was decided to build a table driven system.

A table driven system is one in which a collection of tables define what the device is to do. There are general routines that read these tables and implement the actions called for by the data in the tables. The table already mentioned is the table of command indices that define a task. These are the ones that must be issued in order that the IC-7000 perform the desired task. This is the driving table and there is one of these tables for each of the major tasks that the IC-7000 must perform.

When a major tasks is asked for, the system begins reading the list of command indices defining the task. Once the index of a particular command is made known to the system, general routines look at the additional tables to determine what specifically must be done. Associated with each command index are the following tables:

- The number of bytes to be sent.
- The number of bytes to be received.
- Where the data received is to be stored in the system's memory.
- The location in memory of the data that is to be sent to the IC-7000.
- How the data received is to be processed before storage.
- How the data sent is to processed before sending it out.
- What special routines in the SCREWDRIVER Control System are to be activated.
- The necessity of sending or receiving subsidiary data. That is, the existence of a branch.
- What data integrity checking routines are to be employed.
- The response to be implemented on a failure to communicate.

Since implementation of the commands use common routines, a unified approach to error checking and response is possible. Further, it is easy to increase the capability of the system simply by adding items to the tables without the need to change the primary programs.

Communication with the 7000 SCREWDRIVER Control.

The communication between the TUNE Control and the SCREWDRIVER Control is implemented in a similar, yet simpler, fashion to the communication between the IC-7000 and the TUNE Control. There are sixteen possible commands that can be sent to the SCREWDRIVER Control although not all are implemented. All of the commands tell the SCREWDRIVER Control to do something such as close a relay or start pulse-width modulating the motor current. Other than acknowledging the correct reception of a command only one command asks for data. That command asks for the motor current to be reported to the TUNE Control. The SCREWDRIVER Control is therefore simply a slave to the TUNE Control.

How the 7000 SCREWDRIVER Control System Utilizes the IC-7000's Controls.

Under proper conditions, the TUNER/CALL button on the IC-7000 will put out a signal on the Molex® connector however it will not cause the transceiver to go into the transmit mode unless a response is sent back to the IC-7000. This signal can then be used to initiate actions by an accessory such as the IC-7000 TUNE Control. This signal is used to awaken the TUNE Control from sleep so that there is no computer noise during normal signal reception on the transceiver yet the accessory can be called into action by pressing a button on the front panel of the radio.

Many of the other controls on the front panel of the IC-7000 can be polled as to their state via CI-V commands. For instance, it is possible to learn whether or not the LOCK icon is being displayed. The SCREWDRIVER Control System utilizes the three RTTY Shift Widths to control the manual operation of the antenna motor. The normal 200 Hz shift is selected as the off position for the motor. When the Shift Width screen is being displayed in the RTTY mode, rotating the main dial changes the shift width and this is read by the TUNE Control to learn when the user wishes to move the antenna up or down. The change in shift width can be read via the CI-V commands without transmitting any signal. By capturing the appropriate states of the IC-7000 which can be altered with the panel buttons and dials, it is possible to command an accessory completely from the front panel of the IC-7000.

Of course, utilizing the front panel controls to perform tasks not appropriate to the operation of the IC-7000 means that it is necessary to save the original operating status before the controls have been commandeered and to restore them afterward. The SCREWDRIVER Control System saves all current settings that could possibly be altered during the utilization of the front panel controls. After the SCREWDRIVER Control System has completed the task it was commanded to do, the original status is restored including operating power and mode.

What the 7000 TUNE Control Does During the Tuning Procedure.

Pressing the TUNER/CALL button tells the SCREWDRIVER Control System that it is supposed to wake up and adjust the antenna to find the resonance point of at the new frequency selected by the user. It first saves the operating mode currently being used along with other information. It then asks for the new frequency from the IC-7000 that has been chosen for operation and compares it to the previous frequency for which a resonance was attained. It then changes the IC-7000 to the RTTY mode and begins transmitting at approximately 30 watts of power. This level was chosen in order that the SWR meter built into the IC-7000 would give reasonably accurate readings. The SWR level reported by the IC-7000 is compared with the SWR Target Value saved for the frequency chosen. If the SWR is below the SWR Target value, then the no motor motion is asked for, the transmitter is turned off and the original status of the transceiver is restored.

If the SWR is above the SWR Target Value and the frequency is within 10 KHz of the previous resonance frequency, the TUNE Control uses rising and falling SWR values to determining the direction of the motor motion. If the SWR is above the SWR Target Value and the frequency difference between the newly chosen frequency and the frequency of the previous resonance exceeds 10 KHz, then the direction of travel is determined by the the relative values of these frequencies.

When the SWR falls below the SWR Target Value for the chosen frequency, the motor is commanded to halt and the motor leads are shorted to provide dynamic braking. After a pause, the SWR is checked again in the case that the motor may have drifted past the resonant point. If the SWR is still below the SWR Target Value, the tuning process is halted and the IC-7000 is returned to the original operating status.

If, on rechecking, the SWR is above the SWR Target Value then the motor is reversed and slowed via pulse-width modulation of the motor voltage. Three retries are allowed before the System gives up and signals that something is not right with the set-up. This could occur if the motor has too little friction but it is more likely that the SWR Target Value was set too close to the minimum SWR that the antenna is capable of attaining. In any case, the IC-7000 is returned to its original operating status via CI-V commands.

Special Safety Measures Built Into the 7000 TUNE Control.

When the antenna motor stalls at the end of travel, it will draw many times the normal running current. The level of this current could destroy a motor if the current continues for a long period of time. Some manufacturers of screwdriver type antennas include a resettable fuse internal to their antennas so as to prevent this from happening. However, most do not. It is therefore imperative to detect the stall condition and reverse the motor motion before the motor is damaged. The SCREWDRIVER Control System employs a set-up procedure that determines the level of stall current for the particular motor being used and sets a threshold, which if exceeded, causes the motor direction to be reversed.

Sometimes the antenna is not capable of reaching a SWR value below the SWR Target Value which has been set for a particular frequency band. The SCREWDRIVER Control System will search the entire range of motion of the antenna twice before it indicates that a resonance with a sufficiently low SWR cannot be found. This prevents the motor from running without ceasing.

A resettable fuse has been included in the power line to the antenna motor. This protects the motor and the control from short circuits. In addition, over current detection is provided in the firmware which shuts down the system on the appearance of excess motor current. Reverse voltage protection is provided by a high-current diode. In addition, the power and motor jacks are keyed so that the power plug cannot be inserted into the wrong jack.

The motors and indicators of all motorized antennas operate at a high RF potential. This means that all power lines and control lines have high RF voltages impressed on them. The manufacturers of these antennas always suggest that RF chokes be placed on these lines directly at the base of the antenna. Even with these measures, RF is often present on control and power lines leading to the controller. To help alleviate RF problems, every line coming into the TUNE Control and the SCREWDRIVER Control is heavily bypassed. Still it is imperative that the user of any control device provide adequate RF choking of all leads both at the base of the antenna and at the Control itself.

Additional Service Routines.

The numerical information sent and received from the transceiver and that utilized within the SCREWDRIVER Control is represented in many different ways. There is unsigned binary, signed binary of both 8 bit and 16 bit length. There is BCD and packed BCD (two BCD digits per byte). Obviously it is necessary to have routines that convert the representation of the numbers from one kind to the other. In addition is is necessary to have both binary and BCD arithmetic routines and magnitude comparison routines. Averaging routines are required to smooth data that has the usual noise associated with real physical measurements.

Communication with the user in terms of beeps means that it is necessary to have beep formatting routines. These routines require relative long time intervals compared to the intervals needed for communication or operational timing within the unit. Timing intervals range from 10's of microseconds to seconds depending on the what must be accomplished. Stable timing is therefore essential to smooth operation.

Accessories must be put to sleep during the normal operation of a transceiver in order to eliminate computer switching noise. Waking the accessory entails responding to an interrupt. As the accessory and the user are operating asynchronously (that is they act independently), it is required that an interrupt scheme be implemented to prioritize the signals that come from the device and from the user.

For the SCREWDRIVER Control System there is an additional requirement. The SCREWDRIVER Control unit also operates independently from the TUNE Control unit and must receive commands from it. The TUNE Control unit can be bombarded with interrupting commands from the IC-7000, from the user and from the SCREWDRIVER Control unit. Prioritizing and scheduling these commands requires the development of a robust interrupt scheme.

Conclusion.

Considering all that must take place simply to decide in which direction to move an antenna and when to stop, it is no wonder that the program to accomplish this runs to approximately 50 pages of assembly language code. Yet the program has been successfully developed and the implementation appears to be robust.

The implementation of a novel means of providing the human interface necessary to run an accessory via existing front panel controls and of providing the operational interface necessary to eliminate redundant circuitry has been a challenge but a rewarding one.