Automatic Magnetic Loop Controller
Operating Instructions

Calibration and Storing of Memories

In the example below, I will assume that the antenna covers three frequency bands, 40m through 20m.

Start with all memories empty. If you have previously stored positions, then use the Configuration Menu to perform the command “4-Clear All”.

Note: Storing frequencies outside of the bands, as detailed in Steps 1 and 4 below is not required if the firmware has been compiled with #define ENDSTOP_OPT 2 or 3 (End-stop Switches or Butterfly Capacitor).

1. Tune the Radio to 6,900,000 MHz, verify that the Controller also shows this frequency on its display.

2. Now, using the Rotary Encoder button on the Controller, tune the Antenna for a good match, listening for maximum received noise. We do not want to transmit outside of the 40m band. This memorized position doesn’t need to be very accurate. Tuning to a frequency slightly below the 40m band is to establish a Soft End-stop at the lower end of the desirable range.

3. Store the position. Long push of the Menu/Enact button to enter the Config Menu. Turn Encoder if necessary (only if you were doing something else previously) to select “1-New Position”, and Short push. Now you have stored your first memory.

4. Now tune the Radio to 14,500,000 MHz, verify that the Controller also shows this frequency on its display.

5. Using the Rotary Encoder button on the Controller, tune the Antenna for a good match, listening for maximum received noise. This will in all likelihood take quite a bit of patient cranking of the Encoder, but we will get there. Again, we do not want to transmit outside of the 20m band. This is just to establish a Soft End-stop at the higher end of the desirable range.

6. Perform 3) above, this time a Long Push and a Short Push (no need to select appropriate Menu Item as we are already there) and the memory is stored.

7. Now tune the Radio for 7,001,000 MHz. The Stepper Motor will automatically tune to an approximate position.

8. Using the Encoder, tune for a good SWR. Then, using the Up/Down buttons in a pulsing manner, tune again for a good SWR. This enables the Backlash Compensation function, which overcomes any Slop or Backlash in the coupling between Stepper Motor and Capacitor.

9. Perform 6) above. Long Push and Short Push. First working Memory has been stored.

10. Perform steps 7-9, frequency 7,100,000 MHz.

11. Perform steps 7-9, frequency 7,200,000 MHz

12. Perform steps 7-9, frequency 7,299,000 MHz
13. Perform steps 7-9, frequency 10,101,000 MHz
14. Perform steps 7-9, frequency 10,149,000 MHz
15. Perform steps 7-9, frequency 14,001,000 MHz
16. Perform steps 7-9, frequency 14,100,000 MHz
17. Perform steps 7-9, frequency 14,200,000 MHz
18. Perform steps 7-9, frequency 14,349,000 MHz

Now you should have a set of 12 memories in total (out of 200 possible). The range can be expanded further later on and memories can be added in-between, for example at each 50 kHz interval if necessary, etc.

**SWR Tune and SWR Autotune options, if implemented**

If the SWR autotune feature has been implemented, then an alternate method to step 8 above is as follows:

Normal SWR Tune (Hunt Mode, push SWR Tune or Automatic):
This method hunts for SWR dip within a few hundred steps to either side of current stepper position.
Push SWR Tune. The Radio should automatically switch to AM and provide RF carrier at a low power setting, until Tune has been finished. You should see a message "SWR Tune Success".

SWR Up or Down Tune (push SWR Tune and then Up or Down):
If the normal SWR Tune fails, then the SWR dip is most likely outside of the “Hunt Mode” range. In this case try SWR Up tune by pressing the SWR Tune and then immediately after, press Up. This will change the SWR Tune from "Hunt Mode" to "Up mode". When in "Up Mode", the SWR Tune tunes upward until one of three conditions is fulfilled – Best SWR found, Endstop reached, or timeout. SWR Down Tune works similarly, in the downward direction.

SWR Tune (push SWR Tune button, SW5) can always be used for quick/accurate repositioning of the Stepper for best SWR dip. This may be necessary from time to time due to temperature variations affecting the resonance frequency of the antenna.

If SWR Autotune is ON (toggle button SW4), then an SWR Tune procedure is initiated automatically whenever SWR goes above the set threshold. The threshold is set through Menu Function “11-SWR Tune Thresh”

**Retune Procedure**

If the antenna needs to be retuned slightly due to temperature variations etc, then while at any frequency within the previously calibrated range, use the Encoder and Up/Down buttons to acquire a good match again. This same retune will be applied against all frequency/position calculations until the Controller is turned off.

If there is wish to apply the retune permanently, for instance because the Stepper Motor may have slipped, then a Short push of the “Menu/Enact” button (SW1) (or “Retune” button (SW6) if SWR autotune option is implemented) will apply the Offset against all the stored Frequency/Position memories.
“Cap out of Range” and “Frq out of Range” error messages

The below is only valid if the firmware option ENDSTOP_OPTION 1 “Vacuum Variable, No Endstops” has been chosen (ML.h file, see #define ENDSTOP_OPTION)

The Controller will show "Cap out of Range" when the Capacitor is adjusted to a value outside the range of stored positions +/- a fudge factor of 800 microsteps, equalling 100 steps (#define ENDSTOP_TOLERANCE 800). The Controller will show "Frq out of Range" when the frequency is higher or lower than the outermost points that have been stored. "Cap out of Range" has higher priority than "Frq out of Range", so this will show if both conditions persist.

As per the above, when you are storing the initial set of Frq/Pos pairs, you will see these "...out of Range" messages". This is completely normal and does not inhibit storing of new freq/pos pairs. If the storing is not working, please check where you are in the Menu after >long push< of the Menu/Enact switch. If not at "1-New Position", then turn Encoder until there, and push.

Tuning the Controller in Manual Mode

If there is no frequency information coming from the Radio, in other words the antenna is used in Manual Mode, then the Up/Down buttons have a different function.

Using the example frequencies from the Calibration and Storing of Memories procedure above:

Each push of the buttons goes to the next stored frequency/position, e.g. start position is at 7,045,000 MHz, push once – 7,100,000. Push again 7,200,000, again 7,300,000, again 10,100,000... etc.

A better method in this case may be to switch the Radio to Pseudo-VFO Mode (Menu Item “7-Pseudo VFO Mode”) and then use short pushes of the Menu/Enact to switch the Encoder between VFO emulation mode and Stepper mode. When in VFO emulation mode, the Up/Down switches move stepp 100 kHz with each amateur radio frequency band, and between amateur bands.

Stepper Motor Speed Setup

The torque of a Stepper Motor is inverse to its rotational rate. In other words the faster it goes, the weaker it gets. This has to do with the decay and turnaround rate of the magnetic field of the phase coils each time they are turned on or off or when the direction of current is changed.

Hence it is a bit of a balancing act to determine and set up the maximum useful stepper motor rate. We want to tune between frequencies as quickly as possible, especially when changing between frequency bands. On the other hand, if we go too fast, then the stepper motor starts to slip and calibration is lost.

The Stepper rate is adjusted using Menu Option 5, Stepper Settings.

Start with a modest rate setting and no Speed-Up. There is time to experiment and optimize the Stepper performance once the Controller has been set up with a set of accurate Frequency/Position memories.
Determining the Stepper Rate parameters

The rate is a combination of three factors:

**Max Rate** (maximum rate of change per second, or steps-per-second)

**Variable Rate** (or rate step-up). For instance 4 means that the max rate is 4 times the min rate.

**Microsteps.** Number of microsteps used at minimum rate.

**Steps-per-revolution:**
360 degrees / step-angle,
eg. 360/1.8 [degrees] = 200 steps-per-revolution

Note: The Stepper angle can be set in the firmware to match your setup. See file ML.h,
#define STEPPER_ANGLE 1.8

This is set at 1.8 by default. IF you have a stepper motor with a resolution of 0.9 degrees per
step, then you could change this to:
#define STEPPER_ANGLE 0.9

**Stepper rate in revolutions-per-second:**

revolutions-per-second = steps-per-second/steps-per-revolution,
e.g. 500 steps-per-second/200 steps-per-revolution = 2.5 revolutions-per-second

If microsteps are used, then the actual stepper rate is further divided by the number of microsteps.

**Stepper rate in RPM:**

RPM = revolutions-per-minute = 60 * revolutions-per-second

**Maximum stepper rate examples**

A 30ohm 400ma Stepper motor may not be capable of much more than 100 RPM maximum speed, but
this depends a bit on how much torque is needed to turn the capacitor.

The 1.7A Stepper motor in the second example in the BOM does 360 RPM quite nicely with one of my
antennas.

**USB Pass-through Mode and USB Commands:**

Two of the options available under Menu Item “9-Serial Port Mode”, include a “Passthru” function. The
Pass-through function allows for a connection between the Transceiver and the station Computer, with
the Magnetic Loop Controller being in the middle. The Transceiver connects to the serial port of the
Controller. The Controller USB port connects to the Computer, where it enumerates as a serial port. This
serial port will appear to software as if it were a direct connection to the Transceiver.

When not in Pass-through mode, the USB port has a number of commands available. Some of these are
Power/SWR meter related (same commands as described in my separate Power/SWR meter project).
There are also commands that can be used to backup and restore the frequency/position memories. To
use those, see SimpleMagLoopPosDataBackupRestoreScripts.zip at the bottom of my project webpage for
the magnetic loop controller.

Other commands include built-in debugging tools.
To access the USB port in this mode:

Connect USB port to a computer. On the computer, open a serial port to the Controller, for instance using PuTTY, or using the builtin Serial Monitor in the Arduino GUI.

Note: For the below to work, you cannot be in Passthrough mode (Controller Menu Item "9-Serial Port Mode")

If Arduino GUI, then you start selecting the appropriate serial port, same as when uploading new firmware -
by: Tools->Port->select appropriate port

Then you open the Serial Monitor -
by: Tools-> Serial Monitor

Now you may need to select NL & CR for NewLine.

Now to test, type:
$version <enter>
you should get version information back. If not, then try again. If still not, then verify the NewLine setting in the Serial Monitor.

Now type:
$help <enter>
this will return a couple of screen fills of information on all the various commands available.

To start the serial port debugger, type:
$hexdebug <enter>

Note: For some radios, such as Yaesu FT-450/1200/2000..., Elecraft and Kenwood, you would use $trxdebug instead of $hexdebug

Now you will get on screen all communications between radio and controller, for instance in case of a Yaesu FT-847:

<00><00><00><00><03>  <- Controller asking radio for frequency, once per second
<01><41><23><45><01>  <- Radio answering with 14.123.450 Hz, USB

If you are only seeing the Controller commands, then start by testing the cable by shorting RXD and TXD at the far end of it. This should result in an echo-back of the Controller command, in other words, every one second you should see two lines of <00><00><00><00><03>
Connecting Flex 5000 or 6000 series Radios

The PC software used with Flex Radios can be set up to emulate the CAT protocol used by Kenwood TS-2000 transceivers. This also requires an additional utility by the name of DDUtil.

In this case, you will connect the Magnetic Loop Controller to the Computer, using a cable similar to the one indicated for Kenwood Transceivers, except pins 2 and 3 have to be swapped on the 9 pin connector.

Another option, if you don’t have a free serial port on the computer, is to use a USB-TTL serial cable similar to this one: https://www.sparkfun.com/products/12977

On the loop controller side you would connect TXD, RXD and ground, while leaving VCC disconnected.

Here are a couple of screenshots of how to set up DDUtil, courtesy of Rael, M0RTP:
ICOM CI-V Auto or Poll?

The Magnetic Loop Controller has two serial communication modes for ICOM radios.

The mode “ICOM CI-V Auto” matches an ICOM mode called “CI-V Transceive”. When this mode is enabled, the Radio transmits data over the CI-V bus whenever frequency or mode changes. When this mode is disabled and the Magnetic Loop Controller is set up as “ICOM CI-V Poll”, then the Radio will be polled for frequency information, once every second. Normally this mode is used.

Elecraft K3/KX3 Auto or Poll?

The Magnetic Loop Controller has two serial communication modes for Elecraft K3/KX3 radios.

The K3 and KX3 have an Auto transmission mode intended for Steppir controllers and such. This is the mode that matches the Magnetic Loop Controller setting for "Elecraft K3 Auto". When in this mode, the K3/KX3 will transmit frequency data every time the frequency changes.

Normally you would rather want to use the Poll mode, but sometimes the Auto Mode may be a good way to start when debugging the serial communications.

If you want to experiment with the Auto Mode, then you need to do two things:

On the KX3: In the Menu - Set TECH MD to ON (this makes a few more menu items visible - KX3 Manual, page 39).

Now set AUTO INF to ANT CTRL (KX3 Manual, page 36). As this is a Tech Mode command, it may need to be unlocked first, see description of Tech Mode entries on top of page 35.

On the Controller, Menu Item 7 - Change the Transceiver to Elecraft K3 Auto. What this does is simply to disable a 10 second timeout on the received data, necessary as the KX3 will only be sending data when an actual frequency change has happened.

ToDo: Need to Update the Config Menu diagram on the following pages. Several new menu items have been added since Firmware version 2.07, including:

- ICOM CI-V Address select
- Serial Port Passthrough mode
- SWR Tune Threshold level
- Power/SWR Meter Scales
- Power/SWR Meter PEP period
- Debug Serial on LCD
- New Transceivers - Yaesu FT-747GX, Yaesu FT-990, Yaesu FT-1000MP, Yaesu FT-1000MPmkV, Kenwood TS-440