Emco F1 Mill Upgrade

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Background:

An intact Emco F1 mill was purchased through Ebay in 2010. It had been used in a high school in South Carolina. The machine arrived carefully crated with its original control. Over a year or so, the machine was stripped, cleaned and reassembled. The control was upgraded to include a faster RS-232 port and a front panel button to initiate loading a program from the serial port. A video monitor was also added to simplify running the system. Two major changes were made to the hardware as well (see below).

Over time, it became obvious that the combination of low stepper power and primitive control software made the machine unusable for practical work. At that point, the F1 went into storage. Seven years later, the author moved to a house without a garage/shop and placed the machine in the house. The machine was then upgraded with new steppers, electronics and an old laptop computer running Mach3 control software. The spindle motor and motor drive electronics were the only parts of the original control which were retained.

Mechanical Hardware:

During the original setup of the machine, three hardware modifications were made to the F1. First, due to the availability of a large number of 30-taper NMTB tool holders, the quick change mechanism was removed and the spindle top plate was milled to receive a collar and draw-bar assembly. This is a non-destructive modification to the machine and can be reversed at any time.

Second, the Y-axis of the machine was extended to travel about 125mm rather than the original 100mm. The slide, itself, was already able to accommodate the additional travel. The change was accomplished by installing a longer lead screw made by shortening a salvaged screw from one of the longer axes (X or Z) of a similar machine.

Third, a set of inexpensive digital readouts was mounted, one per axis. These were removed for the current upgrade but the mounting brackets were retained and used to mount limit switches.

Electrical Hardware:

During the early upgrade to the machine, two minor modifications were made to the electrical hardware. The spindle motor was provided with a plug so it could be more easily removed to transport the machine. The machine was also provided with a work light permanently mounted on the left wall.

For the current upgrade, 270oz/in 0.25” shaft Chinese (Longs Motor) steppers were chosen in a NEMA 23 configuration matching the original stepper mounting. The original pulleys were removed and re-installed on the new motors. Because the new stepper shafts are shorter than the originals, Loctite 609 was used to attach the pulleys. This was per information gleaned from Web articles on other F1 upgrades. The pulleys were scrupulously cleaned before assembly and fit with a light sliding fit. To date, this has caused no problems.

The three new steppers came with a typical DB-25 breakout board and a unified driver board to run the motors. The driver board (Longs motor) proved unreliable and a set of three separate Wantai Motor drivers of type DQ-542MA were purchased and used. Those were paired with a 36 volt power supply. The safety chain hardware consists of a set of six micro switches mounted to act as limit switches, an E-stop switch, a commercial charge pump circuit and a set of relays to coordinate system reset. The system also includes a combination 5v./24v. power supply for electronic utility power and to run the safety chain.

A UC100 USB motion controller was chosen to interface between a laptop computer and the DB-25 breakout board for control. That interface has proven reliable under both Windows XP and Windows 7.

An HB04 wired USB pendant was chosen to provide local control of machine functions and to provide a hand-wheel.

A small plastic “project box” was mounted on the upper right side of the machine beside the E-stop switch. This box contains a power switch and “power on” indicator, a hardware reset switch and “hardware reset” indicator and an indicator showing the reset status of the software (through the charge pump circuitry).

All the stepper and safety chain electronics were mounted on an aluminum panel in the the back of the F1. For initial deployment, the old control was placed near the F1 and power to and from the original spindle drive were run to the new control. Eventually, the spindle electronics will be moved into the other side of the F1 cabinet.

Wiring:

Wiring is divided into five areas.

First, the limit switches are chained together with all six in series. The two X switches were tied together and run into a pair of wires in the original X-axis motor cable because that cable moves with the axis. The Y and Z limits were similarly chained together in series and then run through a pair of wires in the Z-axis motor cable.

Second, the new X and Z motors were connected through the original motor cables. Since there was no practical way to use the original Emco motor junction boxes, all wires were soldered and carefully insulated with shrink tubing. The Y motor is inside the enclosure and is wired directly to the control board.

Third, the power and reset control box and E-stop switch were wired down into the enclosure.

Fourth, the main board was wired per the attached diagrams. Generally, items were installed “active low” with their high side connections tied to the appropriate power source and connection to common being made through control circuitry.

Fifth, in the future, the spindle control will be moved from the original control box to the new setup inside the F1 cabinet. This will include moving the spindle power circuit board (which runs directly from 120vac), the associated motor inductor, the speed control potentiometer and the spindle ammeter. The latter two items will be mounted in the control box on the top right of the machine.

Control and Safety Logic:

The machine requires two things to be “reset” before it can run. The first is the hardware safety chain, including the E-stop switch and all limit switches. When the E-stop is released (electrically closed) and the limit switches are clear (electrically closed), the hardware reset button may be pressed. It will momentarily power relay B (RLB) and RLB contact 2 will close, latching the relay on until either the E-stop is pressed or a limit switch is actuated. Upon latching, RLB contact 1 sends a signal to the Mach3 control software indicating that the system is clear of E-stop conditions. At that point, the user may activate the software reset button from the Mach3 screen. Doing that will start output of the Mach3 heartbeat from the computer. The heartbeat relay on the board will close RLA, completing the hardware reset sequence. RLA contact 1 (software reset) and RLB contact 3 (hardware reset) are wired in series and, when both are closed, provide a connection to the control common line (0v.). In doing this, they close RLC contact 1 (stepper enable) which sends an enable signal to the stepper motor drivers. This sequence also enables activation of secondary relays, including the spindle control and two auxiliary control relays when they receive “on” signals from Mach3.

If a limit switch is actuated during a run, it will break the safety chain and release the latch on RLB. At that point, the user may press and continue to hold the hardware reset button and simultaneously press the software reset button on screen in order to use jog commands to move the machine off the affected switch. This must be done with extreme caution as the limit switch system is disabled during such moves and moving the wrong direction will crash the machine.

In a situation where the Mach3 software fails to issue the heartbeat, RLA will drop out and break the reset, stopping the machine. Note that, in that case, the hardware reset light will stay lit because the safety chain is still intact.

Software Setup:

The machine is operated using Mach3 CNC software with one custom setup feature. The M06 tool change startup macro was reprogrammed to ignore the usual pause for tool change if the requested tool is number zero. This facilitates 'safe z parking' of the machine without extra operator input.

Mach3 is fed by G-code generated using Visual-Mill. A custom two-stage post was created and outputs both a subroutine file containing code for each machine operation and a main file which handles tool changes and calls to the subroutines. The two files are manually concatenated for use. This makes code which is 'human readable' and easy to debug and maintain.

The arrow keys and hand-wheel logic have been set up to move the table of the machine as if it were a manual machine, i.e., right arrow moves table to the right. The author has long used Bridgeport Interact machines set up this way and initial experience with Mach3's default of having keys move in the tool direction threatened to be catastrophic. This is a personal choice with proponents on both sides of the argument!

Pendant Modification:

The HB04 pendant proved disappointing. The primary reason for using this device is the hand-wheel (manual pulse generator). The HB04 is equipped with a 100ppr encoder and the signals from it are translated into USB packets and sent back to Mach3 through driver software. This system is fundamentally too slow to emulate a hard-wired hand-wheel. On examination, the author discovered that the encoder unit in the HB04 is connected internally with a small plug carrying 5v., 0v. and “A” and “B” phase signal wires. The encoder unit is unconditioned with weak and poorly formed pulses being generated. The unit was unplugged and a small signal conditioning board was built (see diagram) and installed in the fortuitously empty battery compartment of the wired USB HB04. The power input and conditioned signal outputs were routed to the new F1 control board through a second cable physically parallel to the original USB cable. The inputs were run to Mach3 through two of the breakout board input pins and the performance of this arrangement is satisfactory. Note that this setup still does not approximate the performance of an industrial grade hand-wheel but it makes the system usable.

The five programmable buttons on the HB04 are set up to provide toggling of the manual pulse generator (MPG) menu (TAB in Mach3), MPG mode, step size increment and feed up and down controls.

Note that the display on the HB04 is unreliable. The software driver does not always correctly update the data. That is not a great loss due to the easily readable displays Mach3 provides.

Conclusion:

At this writing, the machine has been used to produce only one part of any complexity. The results are very positive. The part is a milled 2” round in Delrin and contains several drilled holes and a milled counter-bore. The O.D. of the part is round within 0.002” of the target size and exhibits reasonable surface finish for an interpolated curve. The Z depth of the drill and counter-bore features is in normal milling tolerance.

One minor drawback of the stepper setup is that it is slow. Top traverse speed is about 700mm/min (27ipm). This is totally adequate for light machining in a home shop but would not be adequate in an industrial setting. Several attempts have been made to tune the system and this number appears to be about the top achievable speed.

The author invested about $450 in parts for the stepper upgrade and took about 120 hours to assemble and document the system. Given this modest investment, the machine is very satisfactory!