Mark Lerman <mlerman@ix.netcom.com>
May 2010

V 1.01
Changes from 1.00 are in bold and listed below

1- Spring part number and specs changed.
2 – Added choice of pins for 24 volt supply.

How to Modify a Lexmark E260dn Laser Printer for Direct Laser Printing of PCBs

Prologue

This first section is a collection of my musings and experiments with DLP. Feel free to skip it and go directly to Modification, Part 1.

Since we know that toner is a great resist for making printed circuit boards, I have long wondered why we use toner transfer, rather than printing directly on pcbs with a laser printer. After all, if the boards produced by transferring toner first to paper and then to pcbs works well, then putting the toner directly on the pcbs should be even better!

The main arguments against the viability of the process, aside from the mechanics of getting a thick board through a paper thin path, seem to be (a) the drum is too fragile and will be quickly damaged by the boards, and (b) the copper will dissipate the static electricity charge needed to transfer the toner to the board.

Over the last year plus I have been experimenting with Direct Laser Printing (DLP), and it works! I have run hundreds of boards through my modified Lexmark E260dn printer, and I am still using the original drum. Not only can I print on copper clad boards, I can print on aluminum sheets and other metals as well.

I am still experimenting with the process, but trace widths down to 3 mil (.003) widths seem to be easily accomplished. I also believe that double sided boards are achievable, though I have not attempted to make them. Yet.

After tearing apart several different types and brands of laser printers, I have finally settled on the Lexmark E260 as my printer of choice for this modification. It is readily available from Staples for a reasonable price – Currently on sale for $179, with an additional $50 discount if you bring in an old printer for recycling - and is easily modified to pass pcbs. It also comes with a great print utility that allows you to change all the printing parameters very easily.

As I worked on this project, I felt a bit like Edison and his light bulb as I tried many combinations of external transfer voltage sources, modifications of the transfer roller and its high voltage contacts, carriers made of garolite, aluminum and plastics. At one point I even tried “precharging” the board before it entered the printer! It was frustrating to have perfect prints for 3 runs in a row, only to have the next 4 prints turn out horribly. I thought for a while that running the board through a grounding wire before printing (the reverse of precharging) was the answer, but I could not get it to work consistently. Most of my experiments used an external high voltage source of 2500 volts or so, but the required voltage seemed to vary day to day. Things that worked perfectly one day would not work at all the next. I thought it was humidity or temperature changes causing the variations, but was never able to correlate it consistently.

Fortunately, a “run” through the printer takes only a few seconds, and all it takes is a quick wipe with a clean paper towel to clean off the toner for a new run. There were days that I made 50 or more runs through the printer, often without properly smoothing the edges of the board. So much for drum fragility!

One day, using the external transfer voltage supply at 2.5KV, I noticed that after I scrubbed a pcb mounted on a carrier with a water and powdered cleanser mixture that the print was horribly distorted and weak. I had seen this type of print before, but never associated with this “cleaning”. I realized that the problem was that the voltage was way too high. I lowered it to about the internal high voltage power supply voltage and was able to get a perfect image! I did a few runs, but after a while, the images got worse again, this time in a way that seemed to require higher voltage. I finally removed the pcb from the carrier and found that the water solution had gotten between the pcb and the carrier. It seemed that the water solution had allowed the charge to perfectly reach the surface of the pcb through the carrier, and as it dried the charge varied drastically!

Since that breakthrough I have come full circle. The external HV power supply is not necessary, nor is any modification of the transfer roller. I use a simple epoxy coated aluminum carrier with a coating of KY Jelly between the carrier and the pcb and get perfect results (almost) every time!

How to mechanically drive the carrier through the printer also came full circle. I started by providing a plastic guide on the bottom of the toner cartridge to guide the carrier into the drum/transfer roller interface, but eventually found that simplest is best. The way the system is set up the carrier advances and hits the transfer roller below the drum. Friction at the transfer roller then pulls the carrier into the correct position. It works perfectly!

The drum is directly geared to the transfer roller via two helical gears in the E260, but boards over about .032 thick disengage these gears. However, when this happens the stiff carrier is driven by the drive mechanism we have constructed in the front of the printer and by friction between the carrier and the drum and the transfer roller. The mechanism seems to work the same whether I leave the gear on the end of the transfer roller or leave it off, so I just leave it on.

Now on to the Modification of the Lexmark E260 for DLP!

Part One – Mechanical Modification of the printer

Get a copy of the Service Manual for the E260. I have posted it on the Yahoo Homebrew_PCBs group in the files section under Direct Laser Printing. You will need to Use this manual and the pictures I have posted at <http://www.pbase.com/mark10970> to perform this modification.

For the mechanical modification you will need:

1 - A 4mm steel shaft. Doesn't have to be 4 mm, but does have to fit in the slot. The one I used is stainless steel and expensive - $20.56 at McMaster-Carr(1265K39), but a less expensive shaft of regular steel should do as well, and it doesn't have to be metric, though it does have to fit in the slot.

2 - Spring – I bought a 36" piece of continuous spring 3/16 OD x .016 thick wire from McMaster-Carr (9664K74) for $2.98

3 - Rollers – 2 pieces of 4mm ID x 10mm OD x 12mm long spacers from McMaster-Carr(93657A086) at $1.29 per roller.

4 – For the pcb carrier I use a 6x12 inch of .015 epoxy coated aluminum shim stock, McMaster-Carr (9536K47) at $6.39 for a 24 x 6 piece.

Aside from the usual screwdrivers, wire cutters and such, you will also need a dremel type grinder with a routing bit.

To start:
1 - Remove all tape and packing materials.

2 - Install printer to be sure it works.

3 - Remove toner cartridge and put somewhere dark, eg in plastic bag.

4 - Remove paper tray and put it aside.

As you remove each part be sure to keep track of which screws came from where as you remove them - you might want to use masking tape to tape them to the removed parts or label them with a marker. Print a copy of the wiring diagram in the service manual to refer to while doing the mod.

Follow the instructions in the service manual to:

5 - Remove right side cover - it's the side with the access door.

6 - Remove the left cover.

7 - Remove the duplex assembly - necessary because it is under the paper platform. When removing the fuser power supply connector, press the tab on the connector to release it before pulling it out. When removing the power supply note that 1 screw is different than the other 3 - that one screws into plastic. As you are removing the power supply, release the cables, noting which cable goes where and their orientation. Remove the transfer roller cable connector first, using a long nose pliers to pull it sideways out of its slot. Press the tab to release the two and three pin connectors, the multipin connector just pulls out.

8 - Place the printer right side up, open the front door and remove the transfer roller (TR). Be sure to remove the spring under the right bearing and save it. The spring on the left side is attached via the transfer roller cable and should be left in place. The left bearing can slide off the TR, so remove it and put it with the spring. Note that the clips on the bearing are to the outside of the shaft. Also note that the metal bearing can slide out of the bearing clip and get lost if you don't watch out. Put the TR and parts in a safe place. New TR with the spring and bearings are available - see me if you need one.

9 - Remove the fuser. You will not need the fuser, but be sure to save the thermistor cable and the Exit Sensor cable that are mounted on it. You will need these cables and connectors. You will have to take apart the fuser to get to the Exit Sensor.

10 - Remove the main motor gear drive. Be sure to disconnect the fuser link from the front door. See picture. As you lift out the motor gear drive, disconnect the connector. Don't worry about putting it back together - It's very easy since you will be removing all of the hard to put back together stuff. Remove the loose gear and spring assembly that went to the fuser - you won't need them.

11 - Now the fun starts. You will need to remove the mechanism that takes the paper from the paper tray. To do this, first remove the c-ring on the end of the shaft that goes through the paper solenoid. The paper solenoid is just in front of the motor hole, not the blue solenoid on the right. You will not be using these parts, so don't worry if you damage them. Then slide the paper solenoid off the shaft, cutting the wires to the solenoid as you do so. You can free the wires from their guides on the bottom of the printer by simply snapping off the little hooks. Unsnake the wire back to the connector on the controller board and remove the connector.

12 - You can now remove the media feeder mechanism. Since you will not be using any of this stuff, you can either remove it as per the service manual, or just by cutting away the plastic supports and removing it. Much faster and more fun this way - Takes about 30 seconds!

13 - Remove the Toner Patch Sensor. It is held in place by 2 screws on the bottom of the platform, near the media feed mechanism. This device apparently measures the density of toner on the drum and uses the data for some purpose. I assume it is a photoreflector and some leds and tells the printer when the toner is running out, but perhaps it is used to adjust the density of the print. In any case, the printer seems to work just as well without it. I let it sit under the right cover, wrapped in black tape, but the printer works just as well with it completely removed. Unplug the connector and pull it through from the bottom. You can remove it for now and plug it in later, or just save it. If anyone has any information on this device, I would greatly appreciate hearing from them. It might only come into use after the starter toner cartridge is used up and you go to a regular one.

14 - Now remove all three of the sensors on the bottom. They are each held in place by 1 screw. Cut the wires near the sensors and pull the wires through to the controller board. You will not need these sensors, but you will need the wires and connectors.

15 - Put the top back on - it will help maintain rigidity of the structure when you cut the plastic platform.

16 - Place the printer right side up and open the front door. Remove

the manual paper feed platform from the inner part of the lower front cover. Discard it.

17 - Remove the front paper guide with the rollers. It is held on by 4 screws (not the 10 screws on top). While you can actually use this to feed the board, the spring mechanism is not robust and it will quickly start slipping. Discard it.

18 - Remove the paper centering mechanism. Save it and the two screws - you will use this to guide the pcb into the finished printer.

19 - Remove the front door. Disconnect the connector from the controller board and put the door aside for now.

20 - Remove the fan. You won't need it.

21 - Remove and discard the large plastic ventilation guide that goes across the chassis. You will have to remove the top if you had replaced it previously. It is held in by only 1 screw - see picture - but there are plastic pins on both sides and you will have to "spring" the sides apart to remove it. Put the top back on for the next step.

22 - Remove the little plastic fingered thing by the rollers. I forgot about it till I had already masked the chassis, but it's easily snapped off with a screwdriver as shown in the pictures. Discard the scraps.

23 - You are now ready for the big event! You will be cutting away a 7 1/2 inch wide section out of the center of the paper support platform. This space will allow the pcb to travel on a straight path from the front drive roller to the transfer roller. Use the first "rib" on each side as a guide, and a dremel with a routing bit. Lots of plastic chips are produced in this process, so it is important to mask everything except the platform. I used plastic garbage bags and masking tape. Be absolutely sure that the wiring harness and manual feed solenoid wires that run across the bottom of the chassis are loose and away from the cutter. If you cut these wires you will have a bit of a repair job to do! Mask everything, especially the laser mechanism. Be careful handling the chassis because once the cut is made the two halves of the chassis will only be held together by the top and laser platform. The dremel cuts the plastic like butter, so be careful, though it is not essential to makes the cuts perfectly. Be careful around the drive shaft, you don't want to damage it, but removing it is difficult. After the cuts are done, gently sand the cut edges, and vacuum up all the chips.

Now it's time to put it all back together.

24 - First replace the power supply shield. It's easiest to put the multiconducter cable through the middle opening and the other two cables through the front opening.

25 - Next replace the power supply. The transfer roller connector can be put in either before or after the power supply is put in. Be sure to put the connectors in their proper sockets - they can only go one way.
26 - The motor and gear drive is next. Just drop it in and align the shafts to the matching holes if necessary.

27 - To add some rigidity across the back take the rear exit guide assembly and strip off everything down to the plastic. Remove the two screws to remove the plastic assembly that holds the ground comb and roller guides and discard it. Remove the solenoid, all the gears, the small rollers and the shaft. This leaves just a finned plastic piece that can be screwed on the rear of the printer. See the pictures.

28 - We are now going to add a shaft with 2 rollers to the front of the printer. These rollers will mate with the rubber rollers to act as a drive system for the pcb carrier. Fortunately, this is much easier than it might appear. Above each end of the driveshaft there is a convenient slot that is perfectly placed to hold a 4mm diameter shaft. I bought a 400mm piece of 4 mm diameter stainless steel for the shaft and 2 pieces of 4mm ID x 10mm OD x 12mm long spacers as rollers from McMaster-Carr and put them together as shown. I used a small piece of rubber tubing to hold the rollers in place. Since I am using a 6 inch wide carrier, I placed the rollers about 6 inches apart. Next, slide the rubber wheels on the driveshaft so that they are positioned under the rollers. They are held quite tightly by friction, but they do move if you apply enough pressure. Put two rubber wheels under each roller. The position of the remaining wheels is not critical since they are under the carrier.

To spring load the shaft, all we have to do is put a circular spring encircling both shafts. I bought a 20 inch continuous length extension spring (3/16 OD x .026 wire) from McMaster-Carr and cut off two pieces about 7/8 inches long. I formed eyes in the ends and looped them around the shafts. It works well and is quite robust! See the pictures for details.

29 – Replace the paper centering mechanism.

30 – Replace the transfer roller. The right spring goes over a little pin. Position the bearings so that the springs fit into the holes on the bottom then press the bearing holder into place. It should easily click into place.

31 - Next replace the door. Be sure to replace the fuser link in the

slot on the door. Reconnect the cable to the controller board.

32 - Replace the left side cover.

This completes the mechanical modification of the printer!

Part 2.

This section describes the electrical modification necessary for DLP with the E260 and the mcu board that is necessary to make it work. Make a copy of the wiring diagram and connection diagram in the Service Manual and refer to it as necessary.

You will also need a simple microcontroller board (mcu) – see my mcu schematic for a simple one using an ATtiny24.

The printer will not print until the fuser is up to temperature as determined by a thermistor located inside the fuser. As the temperature of the fuser rises the resistance of the thermistor falls. When the thermistor reaches the “right” value, the fuser is ready to go. Fortunately, we don’t have to vary the resistance, we just have to replace the thermistor with a value that tells the printer that the fuser is hot enough to work. For the E260, that value is about 2.5K. So find the thermistor cable and connector, cut it an inch or so from the connector, and solder the resistor between the two leads. Put some electrical tape over the resistor and plug the cable into the controller board.

The printer uses 3 sensors to tell it how the paper is progressing through the printer while printing. Each of these sensors is high (5V) when no paper is present and low when paper is present. Since we have removed these sensors in our mechanical modification of the printer, we have to fool the printer into thinking they are still there or the printer will shut down with a “paper jam”.

We will be using the printer in Manual Feed mode. In normal operation, manually pushing a sheet of paper into the manual feed slot hits the Manual Feed Paper Sensor (MfPS). When this sensor goes low the motor runs for a short burst to pull the paper into the slot. The paper then sits there waiting for a print command from the computer.

When you hit “print” on the computer, the first thing that happens is that the Manual Clutch Solenoid (MCS) is activated. This lets the motor start without moving the paper so that the drum, toner cartridge and fuser start moving, allowing the proper charges to build up on the drum and toner and allowing the fuser to come up to temperature. Once everything is ready to go the MCS disengages and the paper starts to advance.

The leading edge of the paper then hits the Paper In Sensor (PIS). Since the original “feed” is somewhat arbitrary in how much the paper is advanced, I’m pretty sure that this sensor is what triggers the timing for the actual print. This will be important when we do double sided boards.

The paper continues advancing into the printing area, through the Transfer Roller (TR) / Drum interface where the image is transferred to the paper, and into and through the fuser. The final sensor is the Exit Sensor (ES), which goes low when the paper exits the fuser.

Each of these sensors goes low when the leading edge of the paper hits it, and back to high when the trailing edge of the paper exits the sensor. Manually fed paper travels at about 3.87 inches per second through the printer, so an 11 inch long paper traverses the sensor in about 2.84 seconds. Interestingly, paper fed from the paper tray seems to travel at exactly twice the speed.

Once we know the timing, our mcu emulates these sensors directly via 3 mcu output pins. The timing for our emulation starts when the MCS releases and the paper starts to move. I assumed the solenoid is controlled by a simple mosfet so to sense the MCS activation all we need to do is put a load resistor from the mosfet drain to the 5 volt supply. When the MCS is activated, that line (MCSS) goes low and is sensed by an input pin on our mcu. The MCS is controlled by the mcu via a mosfet on our mcu board.

The sequence goes like this:

1 – Press the switch on the mcu board. The mcu pulls the MPFS low, telling the printer that “paper” is present. The printer runs the motor for a short burst pulling the pcb into the rollers. This step can be repeated as necessary to position the pcb.

2 – Tell the computer to print the board image, the same as for toner transfer.

3 – The mcu waits till the MCSS is pulled low by the printer, then it activates the MCS directly, stopping the board from advancing while the printer “warms up”.

4 – The mcu waits till the MCS sense goes high, then deactivates the MCS. The pcb starts rolling into the printer.

5 – The mcu drives the PIS and ES first low then high 2.84 seconds later, emulating the normal timing of the printer. The pcb rolls through the printer and out the other side.

Mcu connections to printer controller board:

1 – MPFS, J23 Pin 2

2 – PIS, J27 Pin 5

3 – ES, J14 Pin 2

4 – MCSS – J25 Pin 2. Cut the solenoid lead from Pin 2 and run a wire from Pin 2 to the MCU.

5 – MCS – Run a wire from the free MCS wire to the mcu board mosfet to control the MCS.

My mcu board has a voltage regulator to produce 5 volts from the 24 volt supply. There are 5 volt sources on the controller board, but since I don't have a schematic of the board I decided to do it this way.

6 – 24 volt supply, **J28 Pin 2 or J26 Pin 1**

7 – Ground, J28 Pin 6. You can remove the connector at J28 and remove the external connector attached at the bottom of the printer. This connector is for a second paper tray and is not necessary.

I attached my mcu board to the inside of the door on the right cover with 4 machine screws and used an external switch also mounted on the door.

You can now replace the right side cover and the paper tray.

This completes the electrical modifications and mcu hookup for the printer.

Part 3.

This section describes the programming for DLP with the E260 using the mcu board on the Yahoo Homebrew_PCBs site. I used an Atmel ATtiny24, but you can use your favorite brand of mcu.

The mcu software needs to do several things:

1 – Tell the printer to load a pcb via a push button switch.

2 – Emulate the 3 paper position sensors that we have removed. These sensors are high (5V) with no paper present and go low (0V) when paper is present.

3 – Sense when the Manual Clutch Solenoid (MCS) is supposed to be activated by the printer. The mcu sensor pin will be high (5V) when the MCSS is not activated and low (0V) when it is activated.

4 – Activate and deactivate the actual MCS via a mosfet. The mcu pin is high to activate the MCS, low to deactivate it.

They say that timing is everything, and in the world of laser printers that is especially true. Since we (or at least I) cannot change the printer firmware, we have to fool the printer into thinking it is simply doing what it is designed to do – print paper.

Before I made my first cuts on the E260 I used a data logger to measure the timing of the sensors and MCS.

The timing goes like this:

1 – Push a piece of paper into the Manual Feed Slot. This hits the manual Paper Feed Sensor (MPFS),driving it low.

2 – The printer starts its motor for a short burst to pull the paper further into the printer. The printer then waits to be told to print.

3 – A “print” command is given at the attached computer to tell the printer to print an image.

4 – The printer receives the print command, and when it is ready, the Manual Clutch Solenoid (MCS) is activated, stopping the paper from advancing while the printer warms up the fuser and gets the drum and toner charges set up.

5 – The MCS is deactivated. This starts the paper moving into the printer and is the starting point for the timing.

6 - .216 seconds after the MCS releases the Paper In Sensor (PIS) goes low as the leading edge of the paper reaches it.

7 – 1.817 seconds later the Exit Sensor (ES) goes low. This sensor is located at the fuser exit.

Using manual feed, it takes an 11 inch sheet of paper about 2.84 seconds to traverse each sensor, so the PIS and ES sensors have to be toggled back to high 2.84 seconds after they go low, and the MPFS has to be toggled back to high at about 2.375 seconds (because the leading edge of the paper is pulled past the sensor in manual feed).

This is somewhat simplified because the MCS actually flips back and forth a few times as the paper traverses the printer, but that is because it is printing flexible paper, and we will be moving a rigid board.

The original short burst (step 2) is somewhat arbitrary in how far it pulls the paper into the printer, so I believe it is the leading edge of the paper reaching the PIS that actually starts the countdown to initiating printing. This doesn't matter much for single sided boards, but will be important if we try to print double sided ones. For that we will have to use an external sensor (see the mcu schematic) to sense where the board actually is so that we print in the same place in the motion axis.

The Program in psudocode:

1 – Initialize with MFCS, PIS, ES all high.

2 – Loop till switch pressed (low).

3 – 50 msec delay to debounce switch.

4 – Loop till switch released.

5 – 50 msec delay to debounce switch.

6 – Drive MPFS low.

7 – If the printer drives the MCS sense low (says print), goto 11 (print)

8 – If the switch is not pressed goto 7

9 – (switch pressed) drive MPFS high

10 – goto 3

Main printing starts here

11 – drive MCS high (to pull in clutch)

12 – loop till MCS sense high (printer releases clutch)

13 - drive MCS low (release manual feed clutch)

Paper starts moving here

14 - wait .225 seconds

15 - drive PIS low

16 - wait 1.825 seconds

17 - drive ES low

18 - wait .325 seconds

19 - drive MPFS high

20 - wait .700 seconds

21 - drive PIS high

22 - wait 1.875 seconds

23 - drive ES high

The printing is now done but must wait to clean up.

24 - wait 5 seconds (for printer to clean up and stop)

25 - goto 2 (start again)

The program for the Attiny24 below is also on the Yahoo Homebrew_pcb site in the DLP folder.

```
;*****************************************************
;* Laser pcb printer                                 *
;* For Attiny24                                      *
;* Mark Lerman                                       *
;* Version 1.10 - Start 3/12/10;                     *
;* Programmed via usb programmer                     *
;* 8.0MHz /8 fuse=1MHz clock                         *
;*****************************************************

.Include "tn24def.inc"

.DEF rmp0 =R16      ;multipurpose register
.DEF rmp1 =R17      ;multipurpose rigister
```

```
.DEF rmp2 =R18      ;multipurpose register
.DEF ticks=R19      ;interrupts counter`


; bit definitions
.EQU mpfs =0        ;manual feed paper sensor
.EQU pis  =1        ;paper in sensor
.EQU es   =2        ;exit sensor
.EQU mfc  =0        ;manual feed clutch
.EQU mfcs =7        ;manual feed clutch sense
.EQU pswitch =2     ;pb switch




.CSEG
.Org $0000

      rjmp     start      ; Reset Handler
      reti                ; IRQ0 Handler
      reti                ; PCINT0 Handler
      reti                ; PCINT1 Handler
      reti                ; Watchdog Interrupt Handler
      reti                ; Timer1 Capture Handler
      reti                ; Timer1 Compare A Handler
      reti                ; Timer1 Compare B Handler
      reti                ; Timer1 Overflow Handler
      rjmp     timint     ; Timer0 Compare A Handler
      reti                ; Timer0 Compare B Handler
      reti                ; Timer0 Overflow Handler
      reti                ; Analog Comparator Handler
      reti                ; ADC Conversion Handler
      reti                ; EEPROM Ready Handler
      reti                ; USI STart Handler
      reti                ; USI Overflow Handler
;
start:
     ldi   rmp0, high(RAMEND) ; Set Stack Pointer to top of RAM
     out   SPH,rmp0
     ldi   rmp0, low(RAMEND)
     out   SPL,rmp0


; main program start
;initializes with mfps, pis and es hi, mfc off
;clutch is not on so paper cannot slide into rollers

     rcall     set_ports      ;set up ports
     rcall     set_ticks      ;set up interrupts
```

```
     sei

;push switch and release to signal paper to grab
;motor twitches, pulling board in
;can repeat switch if necessary
;place pcb

Main:
     sbic pina,pswitch   ;loop till pressed
     rjmp main
     clr  ticks
main_00:
     cpi  ticks,2        ;50msec delay
     brne main_00
main_000:
     sbis pina,pswitch   ;loop till released
     rjmp main_000
     clr  ticks
main_0000:
     cpi  ticks,2        ;kill 50msec
     brne main_0000
     cbi  portb,mpfs     ;signal paper present


;place pcb at rollers
;printer twitches, pulls in pcb and stops


;tell printer to print via computer then
;loop waiting for printer to either say print (mfcs goes lo)
;or press switch again to reposition paper

main_0:
     sbis pina,mfcs      ;loop till printer ready to print
     rjmp main_1         ;printer says print!
main_0a:
     sbic pina,pswitch   ;skip next if sw pressed
     rjmp main_0         ;not pressed, so loop
     sbi  portb,mpsfs    ;pressed, so signal no paper
     clr  ticks
     rjmp main_00        ;then go back to debounce and wait for
release

;time to print!

main_1:
     sbi  porta,mfc      ;then pull in clutch
main_1a:
     sbis pina,mfcs      ;loop till printer says clutch releases
```

```
     rjmp main_1a
     cbi  porta,mfc      ;release clutch!

;paper starts moving, timing starts here!!
     clr  ticks          ;clear int counter
main_2:
     cpi  ticks,9
     brne main_2
     cbi  portb,pis      ;paper sensor lo
     clr  ticks
main_3:
     cpi  ticks,73
     brne main_3
     cbi  portb,es       ;exit sensor lo
     clr  ticks
main_4:
     cpi  ticks,13
     brne main_4
     sbi  portb,mpfs     ;mfs back to hi
     clr  ticks
main_5:
     cpi  ticks,28
     brne main_5
     sbi  portb,pis      ;paper sensor hi
     clr  ticks
main_6:
     cpi  ticks,75
     brne main_6
     sbi  portb,es       ;exit sensor hi

;we are done!
;kill 5 seconds to allow printer to finish up and reset
     clr  ticks
main_7:
     cpi  ticks,200
     brne main_7
     rjmp main      ;and start again!!!


;25 msec interrupts

set_ticks:
     ldi  rmp0,0x02 ;ctc on ocr0a
     out  tccr0a,rmp0
     ldi  rmp0,0x04 ;prescale by 256, =.256msec/ct
     out  tccr0b,rmp0
     ldi  rmp0,98        ;98*.256=25.088 msec/int
     out  ocr0a,rmp0
     ldi  rmp0,0x02 ;0a output compare enabled
```

```
     out  timsk0,rmp0
     ret

;init ports - all sensors hi, mfc lo (clutch off)
set_ports:
     ldi  rmp0,0x0b
     out  ddra,rmp0
     ldi  rmp0,0x04
     out  porta,rmp0
     ldi  rmp0,0x07
     out  ddrb,rmp0
     ldi  rmp0,0x07
     out  portb,rmp0
     ret
;interrupt routine just bumps counter

Timint:
     inc  ticks
     reti
```

Part 4 – How to use the modified Lexmark E260 to do DLP

Now that we have our E260 modified and our mcu board connected and programmed, we are finally ready to do Direct laser Printing of a pcb!

After hundreds of runs and months of experiments I have now settled on the following technique:

The carrier I am now using is a 6 inch wide by 12 inch long piece of .015 inch shim stock from McMaster-Carr. It is coated with some type of tough (epoxy?) non conductive pink paint. I bevel the corners, lightly sand all the edges and put a piece of masking tape over the leading edge to keep it smooth so as not to damage the drum. I have had no trouble with masking tape, but I just bought some Kapton tape which should be a lot smoother. Interestingly, using an uncoated aluminum carrier will not work – it seems to require much less transfer voltage!

I am currently using .032 double sided or single sided pcb stock. I will be doing more experiments with thicker boards later, but I'm pretty sure they will work. The simplest way to hold the pcb on the carrier is with a piece of masking (or Kapton) tape over the leading edge of the pcb. This holds the board in place and provides a smooth transition for the drum onto the pcb. You can also put some tape on the trailing edge of the board (and the carrier), but it doesn't seem to be necessary. The pcb is centered in the width of the carrier with the leading edge about 1.5 inches from the top of the carrier. This isn't critical, but you want the carrier to be smoothly moving through the printer when the actual printing takes place. Adjust the printing margins so that the image is centered on the board.

Note (detailed in the prologue) that once the trailing edge of the carrier exits the front drive mechanism, it is (depending on the thickness of the pcb/carrier, probably friction that carries it through the rest of the printing path. For that reason I like to keep the pcb mounted as close to the leading edge as practical subject to the paragraph above concerns. As a practical matter, it doesn't seem to matter because there is sufficient friction to keep things moving properly.

The key to making DLP work consistently seems to be the contact between the pcb and the carrier. What I finally (after many head scratching sessions) found is that a small amount of water soluble gel – I use KY Gel – between the carrier and the pcb makes all the difference in the world.

To “catch” the board as it comes out of the printer I usually uses a piece of polycarbonate – actually a clipboard from Staples – that I insert from the rear of the printer below the remnant of the paper platform and resting on the power supply. It just sits there. I could glue or bolt it in place, but so far I haven't bothered.

The E260 comes with a very useful utility called Local Printer Settings Utility. This program, installed when you install the printer, allows the changing of virtually every parameter the printer uses. I have not tried all combinations, but a currently use:

1 – Paper. For the Paper Source choose Manual Paper. Under Manual Paper choose Letter Size and Transparency. Texture of Transparency is Smooth, and Weight of Transparency is Heavy.

2 – Quality. Here you have a lot of choices. I have been using 2400 ImageQ, Picture Grade is checked, Gray Correction off, Brightness=6, Contrast=5.

3 – Toner Darkness – One would guess that you would always want maximum toner darkness, but, unlike Toner Transfer, you will probably want to vary this setting, depending on what you are printing. For very fine traces that are close together you need the minimum toner

that works, while for large black areas you might want more toner.

Note that once you have made changes using this utility you need to click on Apply Setting under Actions to make them work.

So to make a board:

1 – Thoroughly clean and scrub the pcb. A light scrub on the back side might help as well. I usually finish off with a quick acetone wipe or two. It is interesting to note that the extreme cleanliness described in toner transfer doesn't seem as important with DLP.

2 – Tape the leading edge to the carrier.

3 – Flip the pcb up and spread a thin layer of KY gel on the bottom of the pcb.

4 – Replace the pcb on the carrier and press it down lightly. Clean the excess KY from the carrier

5 – Put tape on the trailing edge if you want to.

6 – Put the image you want to print on the screen and get ready to print.

7 – Press the mcu button and feed the carrier into the rollers. I like to put a mark on the carrier to show how far to insert it.

8 – Click on “Print”.

9 – The printer will do its thing and the printed board will exit the rear of the printer.

10 – If the board is not perfect just wipe the toner off, clean with acetone and go to step 7.

11 – Peel the board off the carrier. The toner will be tightly stuck to the board by static electricity.

The toner now has to be heat fixed to the pcb. I first tried just cooking it in a toaster oven but found that the traces were uneven with a moderate amount of pitting. I now have been putting the board in a toaster oven at 400 degrees F for two minutes followed by 8 runs through my laminator to fix the toner to the board. This works much better but I am concerned that the laminator may be picking up some bits of toner and depositing them at random places on the pcb. I have bought some Teflon film and will be experimenting with covering the pcb with Teflon before running it through the laminator. The recent thread on tee shirt presses is also interesting, and if they weren't so expensive I might give it a try.

This completes this tutorial on Modification of the Lexmark E260 printer for Direct Laser Printing. All questions and/or comments are very welcome and can be address to me directly <mlerman@ix.netcom.com> or via the Homebrew_PCBs Yahoo group.

Mark Lerman
May 2010