Build Your Own EFIS, Part 3

An introduction to building and programming an Electronic Flight Instrument System.

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In the first of this series of articles, we showed you what to expect from a build-your-own EFIS. The second was a beginning primer on the software to display an EFIS. This month, I will outline the necessary hardware to support an EFIS.

Although there are many fine computing platforms available, we have settled on the ubiquitous PC. The numerous advantages far outweigh its limitations. Components are readily available, software development may easily accomplished on a standard home PC, and most readers will have familiarity with this platform.

With regard to the hardware, if you can build a PC (or know someone that can) from components (motherboard, hard drive, monitor, etc), you can assemble an EFIS for a small fraction of the cost of a commercial system. Although it cannot be approved as a primary flight instrument, it can provide useful (and sometimes valuable) in flight advisory information.

The hardware I will describe is based on commercial-off-the-shelf (COTS) components developed for Mobile Computing (currently a popular buzzword). These are small form factor components available from several sources. I like to think of the result as a Flite PC (FPC).

The PC platform comes in many different form factors. Desktop, laptop, notebook, tablet, hand held, and mobile are among its many flavors. Depending on your aircraft and needs, some of these may be alternatives to building an FPC. The development of the AeroSpectra AD-AHRS was done using a Toshiba Libretto (a small laptop PC). Brackets and mounts are commercially available to firmly install a laptop PC in an aircraft.

So what are the minimum components necessary for an FPC. Well, first we need the main processing unit or motherboard. We also need a display monitor and input device such as a keyboard, touchscreen, or keypad. And, we also need some sort of mass storage device. Depending on the motherboard used, we may also need a power supply to provide the proper voltages.

Both fortunately and unfortunately, there is a myriad of choices for the builder of an FPC. The many choices create initial confusion during the selection process. But, those choices also provide the opportunity for you to create just the system you would like. I will not attempt to fully delineate the selection process here. There really are too many possibilities to do so. Instead, I will provide a few examples to help you get started.

Main Processing Unit

Given the many companies that manufacture PC motherboards, what features should you be looking for to assemble an FPC? And, as important, what types of motherboards should you avoid.

In making your selection of a motherboard, there are several general guidelines that should be followed. It is important to keep in mind that EFIS software is very graphics intensive (that is about all it does, all the time).

1) For graphics intensive operations, fast memory is generally more important than a fast processor. Memory accesses are often a bottleneck in performance. Look for boards with at least 133 MHz memory, although 66 MHz can give adequate performance in a system using only simple graphics. DDR memory is even better.

2) I recommend avoiding all-in-one processors (CPU and video processor on one chip). These will have very marginal performance. These devices were not designed for graphics intensive applications such as an EFIS.

3) Heat is a very important consideration. Select a board that is specified as "fanless". This means the CPU does not require a separate fan. The board itself will still require cooling via a fan or other means if it is confined in the radio stack. "Fanless" boards generally dissipate 16 watts or less.

4) The processor should have at least the performance of a Pentium. Processors of the 486 class and lower will likely be inadequate for the task.

5) I/O should include at least two serial ports, or a serial port and a USB port.

6) A VGA output is a necessity. Except in rare cases, digital LCD support is of little value. These connections are intended for OEM manufacturers of computers with the LCD integrated into the product, e.g. laptop computers.

7) If you plan to use a LCD TV monitor designed for automotive use, a TV output will likely be needed. An external VGA to NTSC converter is another possibility, although my experience has been less than satisfactory. Alternatively, if the display accepts RGB inputs, the EFIS software can change the timing of the VGA to NTSC. For this to be effective, it is important that any digital LCD support be disabled. If the board vendor does not know how to do this, look elsewhere. (It is generally done in the BIOS set-up, but software commands are also possible.) Even then, there can be problems.

8) At least one IDE port for mass storage interface. A Compact Flash socket is also nice, but there are external adapters that may be used. These connect through the IDE port.

If you want to mount your FPC in the radio stack, the recommended location, then several form factors are immediately ruled out. The AT, ATX, mini-ITX, and mini-PC form factors will not fit into the standard radio stack (6.25"). The leading choices that will fit are the EBX (5.25 x 8.0"), nano-ITX (3.75" x 3.75"), and the 3.5 inch (3.5" x 5.7"). The latter two are fairly new form factors. The EBX has been around for quite some time. All three are available with graphics processors, serial ports, USB ports, etc. That is, they are self-contained except for power, keyboard, and display.

Numerous companies manufacture EBX form factor computers. Prices range from less than $400 to well over $1000. The difference in price reflects features and the guaranteed operating temperature range.

The nano-ITX form factor is being promoted by VIA Technologies. As of this writing, it was not yet available, but it is pictured on their Web site. Pricing was also unavailable. It does appear to be a board worth investigating for an FPC.

The 3.5 inch form factor boards are also fairly new. Kontron has a series called JRex. These are priced around $400. Other companies are developing similar boards.

Storage Devices

There are several hurdles using a standard or laptop PC in an aircraft. One is vibration and another is altitude. Combined, they are an anathema to a hard drive. The read/write head of a hard drive flies over the platter at a very low height. As the air density decreases, the head flies lower. The lower the height, the less margin there is for the head to move vertically due to vibration. This leads to more frequent scrapping of the platter by the head. Over time, the platter will become too damaged to reliably store data. Thus, I do not recommend using a hard drive in an FPC.

My own preference is to use Compact Flash. These appear to the computer as a hard drive. The operating system and EFIS software may be loaded on the card using your desktop PC and a simple adapter. On power up, the FPC will boot off the Compact Flash, load the operating system, and be ready to run the EFIS software. A simple autoexec.bat file will automate the loading and running of the EFIS software.

Terrain and other map features are best stored on a CD-ROM or DVD-ROM. Without compression, the USGS Digital Elevation Maps covering all of the U.S. will require many GB. Other map features will add to this total. Thus, a DVD-ROM is the better choice because of its 4.7 GB capacity, but multiple CD-ROM's with regional data may be used.

Input Device

Some sort of input device is necessary to change altimeter settings, adjust the level flight indicator, select modes, etc. A standard keyboard is an obvious choice, but inconvenient to use in flight. There are mini-keyboards available which may be suitable. Some are no larger than a standard business envelope. Be sure that the interface is compatible with the motherboard you choose. Most keyboards and motherboards use a PS/2 connector, but a few now use USB.

A touchscreen has appeal but there are caveats associated with its use. Some screens become difficult to read over time because of tiny scratches from dust and dirt. Special device drivers are needed to interface with the EFIS software. If you are writing your own software, this may be only a minor challenge. But, if you are using commercial software, you will need to check with the vendor about support for touchscreens.

The other choice is a keypad with a standard PS/2 interface. These are readily available, both new and surplus. Some are priced as low as $20. Full stroke as well as flat membrane keypads are available, although the full stroke types are much more common. A keypad is probably the ideal choice. The keypads are rugged and compact and require no special device drivers. The standard PC keyboard driver works with a PS/2 keypad as well as a PS/2 keyboard. The keys may be marked with the various functions , although some would be obvious. Use +/- for altimeter adjustment, up/down arrows for horizon adjustment, PgUp, PgDn for Mode changes (Attitude => Moving Map => Terrain Pan), etc. The software we provide with our EFIS Starter Kit uses these conventions. Other vendors should be able to accommodate them as well.

Display Devices

Judging by the Internet, there may be as many different types of displays as there are amateur aircraft builders. As with the motherboard, I will provide some general guidelines for selection. First, an explanation of some terms is in order.

> <u>VGA Compatible</u>: This is the type of display that may be connected directly to a desktop PC. This is clearly the display type to be preferred. There are some caveats however. First, a display that works well on the desktop may not work well in the cockpit or cabin of an aircraft. Ambient light may wash out the image to the point of illegibility. Second, the display may only operate on the 110 VAC household current.
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> A VGA compatible display has at least five signal inputs. Two of these are digital logic levels (0 and +5V). These are the Horizontal Sync (HS) and Vertical Sync (VS) The other three are analog signals (0 to +0.7V) for the Red, Green, and Blue color (RGB).
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> Standard VGA timing for the HS and VS is 31.5 kHz and 60 Hz respectively.
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> <u>NTSC Compatible</u>: This may mean one of two things. The display may have the same inputs as a VGA compatible display but the HS and VS signals are set for television video signals. This timing is 15.75 kHz for the HS and 60 Hz for the VS.

NTSC Compatible may also mean that the signal is Composite Video with television sync timing.

Composite Video: This is the standard video that a TV station transmits. The HS and VS are combined with the RGB signals into one signal. A special encoder is required to do this. However, with such an encoder, it is possible to use a TV display with a PC. This is not recommended as the results are generally unsatisfactory.

An NTSC compatible display that is not composite video, may be driven directly from a VGA port with the VGA controller card set to output the proper HS and VS timing. This is done through software. This is an option in the software provided with the EFIS Starter Kit.

As always, there are caveats. Typically, digital LCD support in the motherboard must be disabled. Not all motherboards allow this.. The disabling is done in the BIOS set-up. So, this must be considered in the selection of a motherboard. Some graphics chip manufacturers are more cooperative than others about releasing information to do this.

The other caveat is the hardware connections. The display may have a connector that is difficult for the average builder to make connections to. Ribbon type connectors are not uncommon. So, the hardware interface, while electrically simple, may be mechanically very challenging.

The major advantage of using NTSC displays is their ready availability at low cost. This is the type of display used for entertainment systems in automobiles.

A consideration in any display selection is sunlight readability. A display must be bright and have good contrast. Brightness is measured in cd/m^2 (often specified as nits, a label whose origins are unclear). A brightness of at least 300 cd/m^2 is needed for moderate sunlight readability. Some would say a minimum of 1000 cd/m^2 is needed, but such displays are not so readily available at reasonable cost. A minimum contrast ratio of 100 or more is necessary for good viewing. These comments apply primarily to transmissive displays. Transflective (partially reflective) and reflective displays will likely have different required values for brightness and contrast.

There are several types of small flat panel display technologies that are available now or in the near future. Among these are Twisted Nematic (TN), Super Twisted Nematic (STN), Active Matrix (AMLCD or TFT), and Organic Light Emitting Diode (OLED). The first three are Liquid Crystal Displays (LCD). The OLED is currently available only in sizes less than 3”, but larger sizes may be in production in 18 to 24 months. Full color plasma displays in sizes suitable for use in a small aircraft do not appear to be available.

Of the currently in production technologies, the AMLCD will likely provide the best viewing and sunlight readability. But, if OLED’s become available in larger sizes, they may well outperform the AMLCD.

The operating voltage of the display should be compatible with your aircraft electrical system. A 110 VAC only display will require an inverter to operate in the aircraft. Select one that will operate on 10 to 15 VDC if your electrical system is 12V.

From the foregoing discussion, it should be evident that the display is likely to require the greatest consideration in assembling an FPC. The display selection impacts the motherboard selection.

Operating System

Although the operating system (OS) is software, it is software that provides the link between the EFIS software (or any other application program) and the computer peripherals (ports, storage media, keyboard, etc.). For very skilled programmers, an operating system is not required, as the programmer will include all the necessary code to access the peripherals from his program. Many embedded systems do not use an OS. Their peripherals are often no more than a keypad and an alphanumeric LCD, (for example, a calculator). As an aside, early flight simulation programs did not use an operating system. The rationale was that they needed direct access to the graphics registers anyway and the input device (keyboard or joystick) was easy to interface. An operating system provided little or no benefit.

There are major advantages to using an OS, particularly one that is compatible with OpenGL. OpenGL makes the graphics program much easier to write. But, more than that, many graphic devices have graphics accelerator drivers available to work with OpenGL. This can increase rendering speed by a factor ten or more.

My personal preference is for Linux, but Windows, DOS, and many Unix like OS's have OpenGL available to them. (In some cases, like DOS and Linux, the "OpenGL" is actually Mesa, an OpenGL workalike written by Brian Paul.) Linux is low cost, has high performance, and is not proprietary. Some versions have user interfaces that are very easy to use.

Power Supply

As a conservative estimate, the power required by a low power motherboard will be about 20W. Allowing another 15W for a DVD-ROM, we have a total of 35W. Thus, a conservative rating for the power supply should be 45W. If the display selected requires voltages other than the 12V aircraft bus voltage, then its power will need to be included in the total. (Some displays from NEC specify 9.5V. They work well on 10V and a simple 10V linear regulator is all that is needed.)

For flexibility, separate power supplies may be used for the motherboard and the DVD-ROM. It is not necessary, but packaging the FPC may be easier. For a selection of available power supplies, visit http://www.jameco.com and http://www.mpja.com.

Choosing a DVD-ROM that uses only 5V will make the power supply selection easier. Five volt only power supplies are more readily available.

Since the aircraft bus voltage can range from 10 to 15 volts in normal operation, supplies rated for at least this range should be used. Power supplies that specify 12V +/- 10% on the input are likely to cause problems in service.

EMI/RFI

Good shielding and grounding practices are essential to preventing Electromagnetic Interference (EMI) and Radio Frequency Interference (RFI). Test is the watchword here. As you power on the various parts of your hardware, as a minimum, use a scanner to check for interfering signals in the aircraft communication and navigation bands. (A laboratory grade spectrum analyzer would be even better, but few of us have access to such sophisticated equipment.) Continue to test at each step, all the way through the final installation in the aircraft. Since most scanners will not cover the DME/TACAN or GPS bands, it is particularly important to verify that this equipment is not compromised by operation of your EFIS.

Alternatives

If assembling your own FPC does not appeal to you, but you would still like to have the result in your aircraft for an EFIS or other reasons, there are companies which specialize in building Mobile Computing platforms (PC's). A search of the Internet will yield numerous possibilities. Keep in mind the recommendations of this article when choosing a Mobile Computing platform as your FPC. The vendor should also be able to help in your selection.

Conclusion

This article has only briefly outlined the process of building and installing an FPC in an amateur built aircraft. For the reader so inclined, there is much more information on the Internet – too much to digest it all. But, I hope I have provided enough information to begin the quest.

While challenging, building an FPC is within the capability of many amateur aircraft builders. As more vendors offer products suitable for Mobile Computing, this task will become even easier.