Introduction
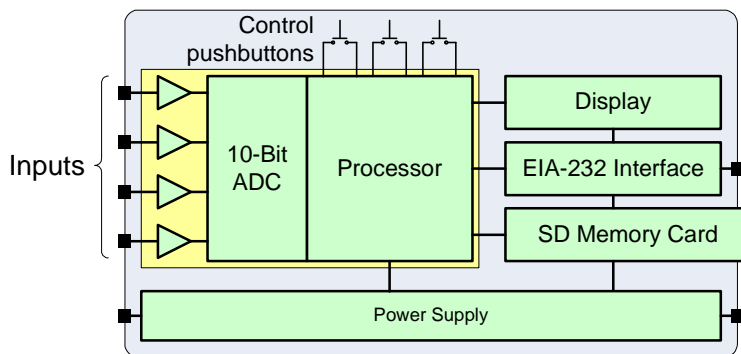
Amateur radio astronomers sometimes need to log data from sensors such as receivers and magnetometers but do not wish to or cannot leave their PC turned on for long periods. They need an autonomous datalogger that can be operated from a battery and has removable storage, and it must be inexpensive. The Elektor Datalogger "Deluxe" (EDL) described here fills that need.

A datalogger is a device that periodically samples an input signal and stores the samples for later manipulating and processing. The EDL samples low frequency analog signal voltages, converts them to a digital format and stores the digitized samples in files on a removable Secure Digital (SD) memory card. The files may be read and displayed by common PC spreadsheet programs. The datalogger operates from nominal 12 v dc and is suitable for battery operation. A block diagram is shown in Fig. 1.

Fig. 1 – Elektor Datalogger "Deluxe" block diagram. The 10-bit ADC (analog-digital converter) and processor functions are combined on the PIC18F452 microcontroller.

The removable memory card makes this datalogger somewhat unique when compared to many commercial dataloggers, which require a full-time connection to a PC for data collection and storage. Most commercial dataloggers with memory card storage cost three or more times as much as the EDL.

I use the EDL for sampling the signal output from a very low frequency (VLF) receiver used in Sudden Ionospheric Disturbance (SID) studies, among other things. This application is not the only one possible – some additional examples are gathering environmental data such as temperature and barometric pressure, detecting and storing discrete on/off voltage changes, or sampling and storing any low frequency signal within the voltage range of the inputs (0 to +5 v).

The Elektor Datalogger has the following basic specifications:
- 1 to 4 analog input channels, 0 to +5 v input range
- Provisions for input voltage limitation
- Provisions for input voltage offset up to 5 v
- Manual, external and timed trigger modes
- Timed trigger intervals from 1 second to 9999 minutes
- Data storage on Secure Digital (SD) memory card (FAT16 format)
- Selectable plain text or comma-separated variable (CSV) file formats
- Up to 65,000 samples per data file
- Up to 9999 files per SD card
- PIC18F452 microcontroller operating at 20 MHz
- 10-bit analog-to-digital converter (ADC) with resolution of 1 part in 1024
- Firmware written in C and compiled with MikroC (source code available)
- PCF8583 real-time clock/calendar with battery backup
- 4-line x 16-character liquid crystal display (LCD) with backlight

- EIA-232 serial port (for firmware programming)
- 12 – 18 v dc input voltage range
- 25 – 80 ma input current range

Kit

The EDL may be built from scratch or from a kit. The printed circuit board (PCB) layout files are available via free download from Elektor's website (www.elektor.com). A professionally made PCB by itself and a preprogrammed microcontroller also are available. The full kit costs a little over US $120 (plus US $16 shipping to the USA) and includes all PCB-mounted components, LCD module and preprogrammed microcontroller but does not include an enclosure. All controls, terminal blocks and interfaces are PCB-mounted (Fig. 2), and they must be removed if the EDL is installed in an enclosure. A reprint of the original Elektor magazine datalogger article (March 2008) is included with the kit.

Fig. 2 – Completed Main PCB ready for integrated circuit (IC) and clock battery installation. Dimensions are approximately 90 mm wide x 105 mm high. The LCD module (not shown) mounts over the main PCB and plugs into the header on the PCB's upper-left edge. The SD memory card plugs into the socket on the upper-right. Signal and power connections are through the terminal blocks on the lower edge. After this picture was taken, I removed the three pushbutton switches (above terminal blocks) and DB-9 connector (lower-right) and mounted comparable units on the enclosure.

The preprogrammed microcontroller available from Elektor has version 1 firmware on it. A later version 2 firmware is available for download from Elektor's website, and I recommend it rather than version 1. The firmware includes a bootloader so that a new or existing microcontroller may be updated quite easily.

There are no step-by-step instructions, but the kit is simple enough not to require them. The documentation describing the EDL operation is somewhat limited and scattered throughout the magazine article. As a result, first-time use is confusing. For my own use and to help others with the EDL, I wrote a more detailed Elektor Datalogger User Guide.[1]

It is possible to use the EDL without an enclosure, but it will be susceptible to damage, short circuits if set on a conductive surface, electrostatic discharge damage from handling and environmental hazards. If you decide to install the EDL in an enclosure, as I did, you should not install the pushbutton switches or DB-9F connector on the PCB during kit assembly. Since the EDL's EIA-232 interface uses only three wires, I replaced the DB-9F connector with a stereo phone jack to save space and simplify installation.

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[1] Available from: http://www.reeve.com/Documents/Datalogger/ElektorDLUserGuideR1-0.pdf

Since the supplied switches and interface connector are designed for PCB mounting, they must be replaced with equivalent panel-mounted parts and wired to the PCB. The power and input/trigger leads are connected to the EDL through a screw-down header mounted on the PCB. These leads need to be extended to a panel-mounted header. Readers wishing to duplicate my setup can find a complete material list in the User Guide previously mentioned.

Power Consumption

The Elektor Datalogger was not designed for low power consumption. Although the microcontroller itself is a relatively low-power device, certain hardware and program features of the EDL preclude very low-power operation.

Version 1 firmware kept the LCD backlight on all the time, resulting in a power consumption of about 720 mw continuous (57 ma at 12.6 v). Version 2 firmware modified the operation such that the backlight automatically turns off after 60 seconds, reducing the consumption to about 330 mw (26 ma at 12.6 v). The backlight can be turned back on for another 60 second time period by pressing any one of the three pushbuttons. Also, there is an LED power-on indicator that glows continuously and an associated current limiting resistor dissipating about 30 mw, or almost 10% of the total.

I used a 12 v sealed lead-acid battery with 800 mah capacity, which provides about 31 hours reserve time with version 2 firmware. Removing the power-on LED altogether would increase the reserve time by about 9 hours; however, I wanted to have a power indicator so I replaced the stock LED with a flashing LED having a 28% duty cycle. This reduced the LED power consumption to around 8 mw, providing about 6 hours additional battery reserve time.

Signal Sampling

Each signal voltage sample is stored with a timestamp. The timestamp is determined by the built-in real-time clock (RTC). The RTC uses a relatively inexpensive 32.768 kHz crystal that I found to be surprisingly accurate. An oscillator trimming capacitor is provided so the frequency can be set precisely; however, the crystal can be expected to change frequency with temperature variations and age. The RTC includes a replaceable battery (CR2032) that allows the EDL to keep time even with no external power.

The signal sample amplitude is stored as an ADC value and not a voltage value (Fig. 3). The samples range from 0000 to 1023, where 0000 corresponds to 0 v input and 1023 corresponds to 5 v input. Thus, the basic voltage resolution is approximately 5 mv.

Fig. 3 – EDL sample data. The shaded text does not appear in the stored data but is provided here to identify the columns. The interval time (1 sec), number of channels (1) and start time and date are at the top of the stored data file.

Sample No.	Value	Hour	Minute	Second	Day	Month	Year
Interval 1 sec	1 channels	22:54:29	09/12/2009				
1	65	22	54	29	9	12	2009
2	65	22	54	30	9	12	2009
3	65	22	54	31	9	12	2009
4	65	22	54	32	9	12	2009
5	64	22	54	33	9	12	2009
6	65	22	54	34	9	12	2009
7	65	22	54	35	9	12	2009

Since the EDL does not store signal voltage values, downstream scaling is accomplished by multiplying the sample value by the factor 5/1023. For example, a sample value of 499 corresponds to a signal input voltage of 499(5/1023) = 2.439 v. This scaling is easily done in a spreadsheet program. The sample values from each channel are displayed on the LCD (with version 1 firmware only the first channel is displayed). The display also shows the time remaining to the next sample (Fig. 4).

Fig. 4 – The display shows date and time on the first two lines. The sample value for each channel is shown on the lower-right and time remaining to the next sample on the lower-left. The pink material at the bottom of the enclosure is a cushion for the small sealed lead-acid battery, and the green block in the middle is the signal input terminal block. The translucent polycarbonate enclosure is 110 mm wide x 190 mm high x 60 mm deep.

The PIC18F452 datasheet recommends the signal source impedance should be less than 2.5k ohm to minimize measurement errors due to the pin leakage currents; however, the datasheet allows that the source impedance to be as high as 10k ohm. For reasons unknown to me, the EDL designer used 10k ohm resistors in series with the microcontroller input pins, forcing the source impedance to be at least that value. The higher value not only affects measurement error due to leakage but also the proper charging of the charge holding capacitor and associated input time constant. The effect of this is that the actual signal source impedance must be very small. I made no measurements to determine the error introduced by the 10k ohm input resistors (if any) – I justified my laziness by not needing maximum accuracy in my applications.

Basic analog-to-digital conversion error is determined by the microcontroller ADC. In the case of the PIC18F452,

the maximum linearity and gain errors are specified as ±1 LSB (least significant bit) and offset error is specified as ±1.5 LSB. These error specifications are typical for microcontroller ADCs. In practice, the actual errors from all internal causes probably are in the range of ±0.5 LSB. Since the EDL is a simple datalogger and does not use guarding or special shielding and grounding to minimize measurement errors, users must take care that signal and power supply leads are short and the power supply itself is not noisy. Of course, when the EDL is operated on a 12 v battery, power supply noise is insignificant.
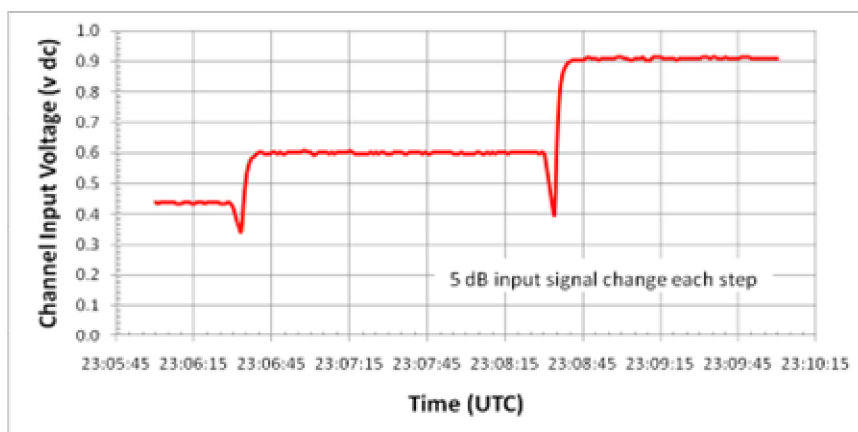
Operational Use

Initial EDL setup requires little effort and includes setting the clock, file format, number of channels and trigger mode. These all are set using the three pushbutton switches. Signal connections are made through a screw-down terminal block. Signal input voltages must be limited to the range between 0 and +5 v. For signals that have negative amplitudes, the EDL has a variable output voltage that may be used to offset the signal input up to 5 v, but the maximum positive input voltage still must be taken into account when using the offset.

The EDL has selectable preset 1 or 60 second sampling intervals or variable intervals from 1 to 9999 seconds or 1 to 9999 minutes. It also can be externally triggered by application of a voltage to the trigger input or manually triggered by pressing one of the pushbutton switches. At this time, the most common EDL application in my observatory is to periodically sample the output from a sensor such as a VLF receiver. In the case of a VLF receiver, a 10 or 60 second sampling interval ordinarily is used. I use downstream processing (averaging or sample selection) to reduce the noise in the data.

After the data samples are collected, the SD memory card is removed from the EDL and placed in a card reader connected to a PC. The EDL must be turned off before removing or replacing the SD card. I experienced problems using older 16 and 32 MB SD cards, but a recent 512 MB card worked fine. A typical datalogger run will save data in the CSV format, which may be imported directly into a spreadsheet program for processing and plotting (Fig. 5).

Fig. 5 – Test data plot for UKRAA VLF Receiver

Conclusions

The Elektor Datalogger is a relatively inexpensive datalogger that amateur radio astronomers should find useful as a general appliance in their observatories. The removable storage and low voltage dc operation allows portability and operation without a local power source or permanent PC connection. It has sufficient resolution and input voltage range for many applications and is simple to use.

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