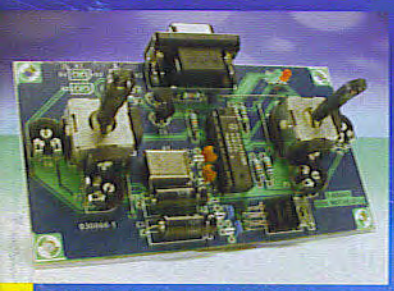
JANUARY 2004
£3.70

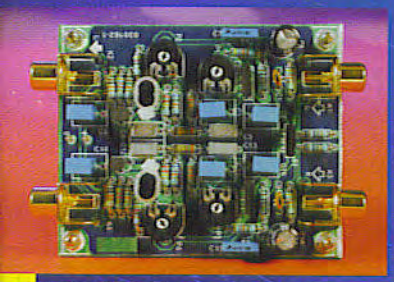
ELEKTOR ELECTRONICS

THE ELECTRONICS & COMPUTER MAGAZINE

www.elektor-electronics.co.uk



FMS Flight Simulator Encoder



RIAA Preamp with FETs

64-K 80C552 Flash Board

LED Roulette

OTL Headphone Amp

Multi-event Alarm Clock

CLIMATE LOGGER

captures temperature and relative humidity

9 770268 451111 01

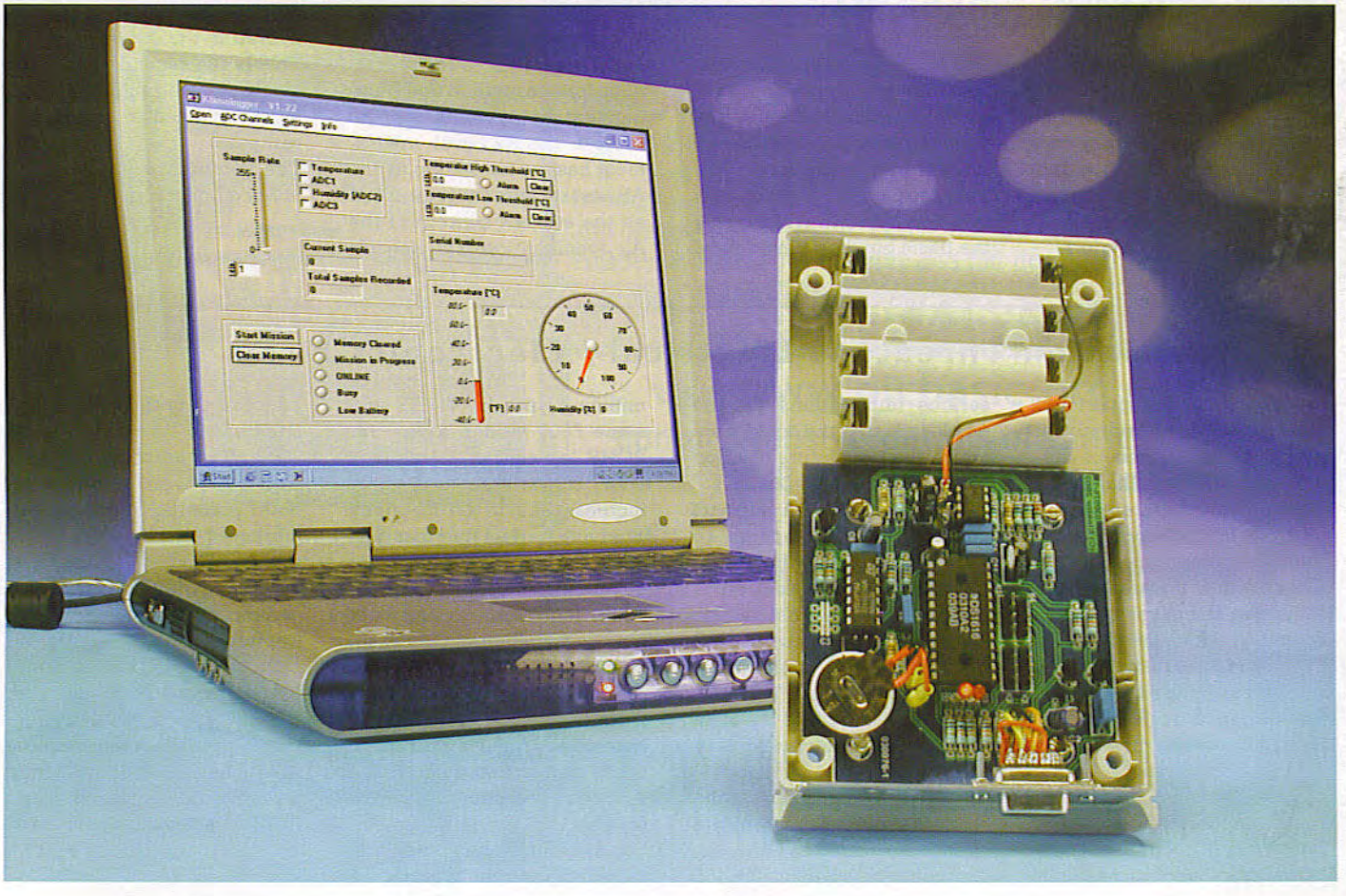
Climate Logger

Recording temperature and humidity

Design by T. Poms

http://chripo.icb.at/Rooney

This electronic alternative to mechanical temperature and humidity recorders is a very compact standalone unit which draws very little current. The Dallas DS1616 device used comes already equipped with a temperature sensor, and besides a humidity sensor we can add a range of other sensing devices. The collected data can be transferred to a PC or notebook over an RS-232 port for analysis by user-friendly Windows software. The system can also be connected to a microcontroller board.



The climate logger operates completely autonomously while it is carrying out a 'mission' (measurement sequence), and can run on battery power for a long period in this mode. The device can, for example, be left in the refrigerator or in the wine cupboard to continuously record the temperature and humidity. The Windows-based software running on a PC is used not only after a mission to download and analyse the stored data, but also before a mission to configure the data logger. With the aid of the software, both the sample rate and the selection of which channels are to be recorded can be configured.

The version of the climate logger described here connects to the PC over a serial interface. The planned USB version previewed last month is still in development.

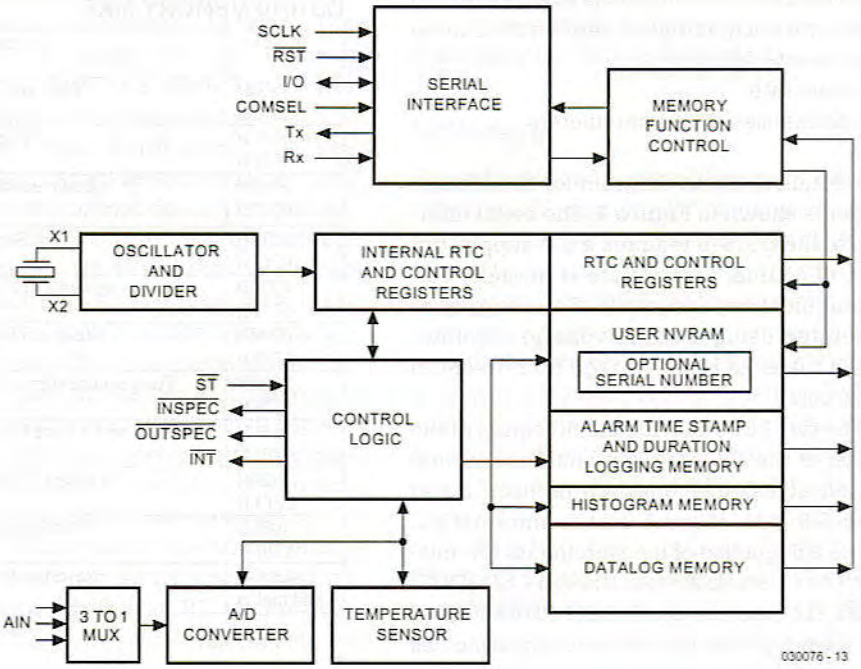


Figure 1. Internal circuit of the DS1616.

DS1616

'Intelligent' temperature sensors produced by Dallas frequently appear in circuits in *Elektor Electronics*. There is a wide range of ICs offering a wide range of peripherals, so that the ideal device can easily be found to match the requirements of any particular application. A built-in memory comes in very handy for building a temperature logger. The DS1616 device used here is a particularly well-equipped member of this series of temperature sensors.

The internal block diagram of the DS1616 is shown in **Figure 1**. Besides the temperature sensor and the memory the most interesting feature is certainly the analogue-to-digital converter, which has a resolution of 8 bits. The converter is equipped with a 3-to-1 input multiplexer. It is possible to use the converter to accurately measure three external voltages in the range 0 V to 2 V, and to store them along with the internal temperature signal.

The DS1616 also offers a real-time clock driven from a built-in oscillator (which requires a 32.768 kHz watch crystal). The clock is also used to drive a simple serial RS-232 interface to allow alarm times, sampling clock rates, timestamps and time delays to be retrieved from the device's memory. It is also required for scanning the measurement channels and is needed for certain commands such as *Clear Memory* to be carried out.

The DS1616's built-in temperature sensor determines the operating temperature range of the climate logger at –40 °C to +80 °C. The components used for the remainder of the circuit, including the humidity sensing circuitry, must also be specified for at least this temperature range, or the overall specifications of the climate logger will be degraded (**Figure 2**).

Memory Map

The DS1616 offers 2048 bytes of memory divided into pages of 32 bytes each (**Figure 3**). The *RTC and Control Registers* and the *User NV RAM* areas can be written to. The use of the RTC and control registers in our climate logger application will be discussed further in the 'Software' section below. All the other locations can only be read. Each read command contains the start address from which reading is to begin, and data are then transmitted until the end of the page is reached. This means that each read command will cause a maximum of 32 bytes, plus a 2-byte CRC generated in hardware by the DS1616, to be sent to the master device (a PC in this case). The CRC (cyclic redundancy check) allows errors in transmission to be detected, so that the command can be repeated if necessary.

The RAM is non-volatile (NV), which means that the memory contents are preserved even when power is lost. This RAM is used to store important parameters when the master software is exited: these values can then be reloaded by the software when it is restarted at a later date. The following parameters are stored by the current version of the software:

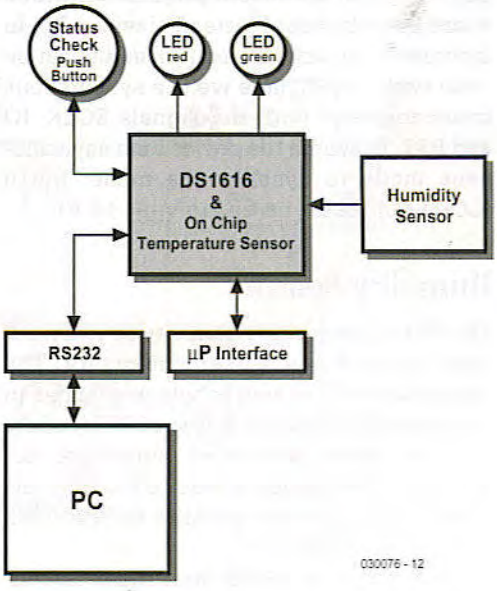


Figure 2. Block diagram of the Climate Logger.

- The measurement channels selected for the most recently initiated sequence of measurements
- Sample rate
- Performance-related parameters

The detailed circuit diagram for the climate logger is shown in **Figure 4**. The serial interface of the DS1616 requires a 5 V supply, but only, of course, when there is actually any communication occurring. This supply is generated using a 78L05 voltage regulator which takes its input voltage from the PC's COM port.

The two LEDs provide an indication of the status of the DS1616. The pushbutton connected across JP1 must be pressed for at least 0.5 s to request status information. Before a sequence of measurements (or 'mission') has been initiated, the red LED ($\overline{\text{OUTSPEC}}$, D2) and the green LED ($\overline{\text{INSPEC}}$, D3) will flash together four times. If a mission has been initiated, but the first measurement has yet to be taken, the LEDs will flash four times alternately, starting with the red LED. A sequence of measurements can be initiated either from the PC, or, in standalone operation, by pressing the pushbutton. See also the software description below and the guide to operation at the end of this article.

The software allows threshold values to be defined. If a measured analogue value (an external voltage or a reading from the temperature sensor) is above (or below) the threshold value, a bit is set in the Status 1 register. When this happens, the red LED (D2) flashes four times. If the user-defined thresholds are not crossed, the green LED (D3) will flash four times.

An interface is also provided to allow the data logger to be used in conjunction with a microcontroller board instead of with a PC. In contrast to the asynchronous communication used with the PC, here we use synchronous communication with the signals SCLK, IO and RST. To switch the device from asynchronous mode to synchronous mode, pin 6 (COMSEL) should be tied to V_{CC} (+5 V).

Humidity Sensor

The HS1101 capacitive humidity sensor measures relative atmospheric humidity. The capacitance of the sensor, which changes in proportion to humidity, is first converted into a pulse-width modulated signal. A fair amount of electronics is required to turn this signal into a voltage suitable for the AIN2 input of the DS1616.

One half of a TS556 dual timer is connected as a free-running multivibrator, generating a regular squarewave signal. The RC-

DS1616 MEMORY MAP

Address	Register definition	Page(s)
0000H 003FH	RTC and Control Registers	0 - 1
0040H 005FH	User NV RAM	2
0060H 0217H	(Reserved for Future Extensions)	3 – 16*
0218H 021FH	Serial Number	16**
0220H 027FH	Alarm Time Stamps and Durations	17 – 19
0280H 07FFH	(Reserved for Future Extensions)	20 – 63
0800H 087FH	Temperature Histogram (63 Bins of 2 Bytes Each)	64 – 67
0880H 08FFH	ADC Channel 1 Data Histogram (64 Bins of 2 Bytes Each)	68 – 71
0900H 0FFFH	(Reserved for Future Extensions)	72 – 127
1000H 17FFH	Datalog Memory (64 pages)	128 – 191
1800H and higher	(Reserved for Future Extensions)	192 +

* First 8 bytes
** Last 8 bytes

Figure 3. DS1616 memory map.

combination formed by R1, R2 and C1 sets the period at about 1 s. IC1.A triggers the second half of the timer, which operates as a monostable multivibrator, creating the pulse-width modulated waveform. At its output we have a lowpass filter which finally turns the PWM signal into an analogue DC voltage proportional to the atmospheric humidity. Depending on the characteristics of the sensor, this voltage varies from approximately 990 mV to 1190 mV. The signal must now be processed so that it lies in the range 0 V to 2 V, so that good accuracy can be obtained using the analogue inputs of the DS1616. According to its datasheet, the sensor capacitance only varies between 161 pF and 200 pF, and the electrolytic capacitors used have a wide tolerance: this means that the circuit will require calibration.

This facility is provided using instrumentation amplifier IC3, which amplifies the generated voltage by a factor of 10. Very high resistances are used here in order to keep current consumption low. The output signal is also passed through a high-value resistor before being taken to the analogue input of the DS1616.

The voltage VCC_{HUM} is generated using an LM385-2.5. This produces a fixed reference from the varying battery voltage, used to supply the whole humidity measurement circuit as far as IC3. This ensures a good power supply rejection ratio (PSRR) figure.

A Compact Data Logger

The climate logger is constructed on a single-sided printed circuit board (**Figure 5**). There are no wire links, and construction should not present any difficulties. The ICs should be fitted in sockets. Terminals are provided for all the external connections, including for the 9-way sub-D socket for the RS-232 interface, and for the two batteries BT1 and BT2. BT1, which powers the humidity measurement circuit, has to supply a considerably greater current than 'backup battery' BT2, which only supplies the DS1616 when it is in autonomous mode. This means that BT1 should be made up from AA or C cells in series, whereas BT2 can just be a coin cell (see also the text box). BT2 also determines how long as the climate logger can retain its stored data and settings, while, BT1 only determines for how long humidity measurements can be taken.

The enclosure must not only house the printed circuit board, but

also the batteries and their holders, the pushbutton, and the RS-232 socket. The humidity sensor should be soldered as close as possible to K1. It is not recommended to mount the sensor on the side of the enclosure, since this will involve a greater cable length. The enclosure should not be airtight so that atmospheric humidity is present at the humidity sensor.

Calibration

Two reference capacitors (or combinations of capacitors) of 161 pF and 200 pF are required for alignment. The values should be checked directly by measurement. First connect the 161 pF capacitor to K1, and measure the voltage at the output of the lowpass filter using a high-impedance multimeter. The offset voltage (the voltage between the input of preset P1 and ground) should have the same value. The voltage at the output of IC3 should be between 2 mV and 7 mV. The voltage cannot be set to exactly zero, since we cannot do anything about the offset voltage of the operational amplifier. Now connect the second capacitor to K1 and once more measure the voltage at the output of the lowpass filter. The value should be about 200 mV higher than the previous reading with the smaller capacitor. Since we have a voltage variation of about 200 mV over the humidity range, and a voltage range of 0 V to 2 V is required, the amplifier circuit is configured for a non-inverting gain of 10. Preset P2 at the non-inverting input allows the gain to be trimmed. When 2.00 V is measured at the output of the operational amplifier, calibration has been successfully completed.

Software

The software runs under Windows 2000 and Windows XP; versions for Windows 95 or 98 are not currently available but may be developed later (watch the author's website). The main window allows control over the main settings and shows real-time measurement results (**Figure 6**). The measurement channels (temperature, ADC1, humidity/ADC2 and ADC3) can be individually enabled and disabled. When the DS1616 is not 'on a mission', the temperature and humidity values are measured once per second (assuming the corresponding measurement channels are enabled) and the results displayed. This feature is implemented using a timer whose default period is one second. However, this

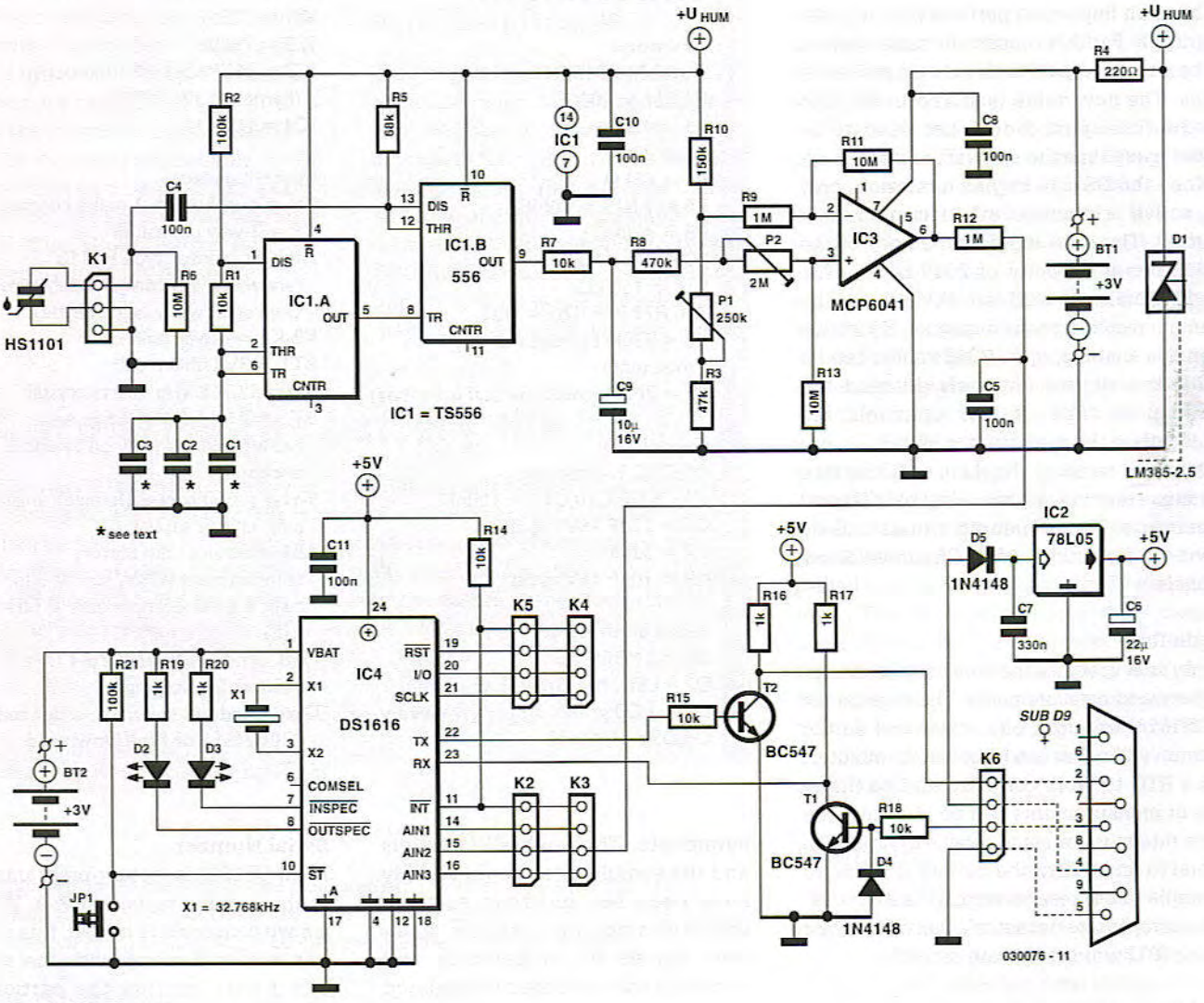


Figure 4. Circuit diagram of the Climate Logger.

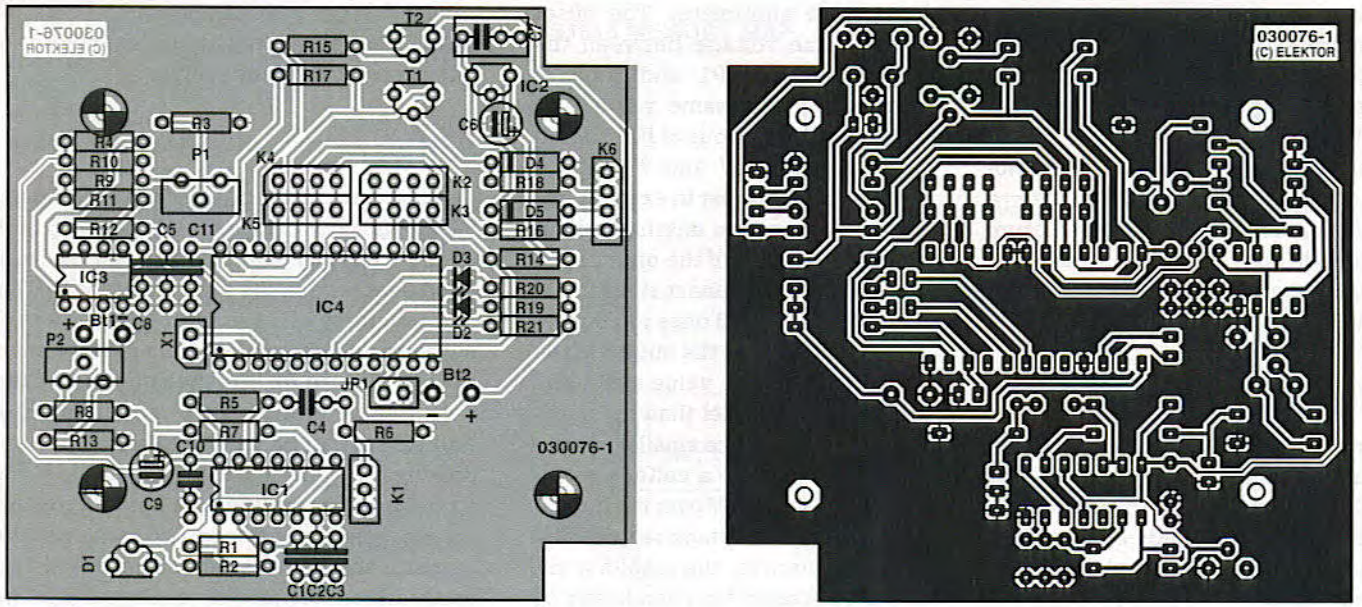


Figure 5. Layout and component mounting plan for the single-sided printed circuit board.

timer requires CPU power to operate, which can have an impact on performance in older computers. For this reason the timer period can be set as desired under *Settings/Performance*. The new value is stored in RAM so that the timer period does not need to be entered every time the software is started up.

When the DS1616 begins a mission, only the active channels are sampled and recorded. The data logging memory of the DS1616 has a capacity of 2048 bytes. The more channels are enabled, the shorter the maximum recording time available. If just one channel is enabled, up to 2048 values can be recorded; with two channels enabled the maximum is 1024. If four channels are enabled, then the maximum is 512.

The main window displays only the two most important values: humidity (ADC2) and temperature. The remaining values can be shown by selecting *ADC Channels/Show Channels*.

Sample Rate

'Sample rate' specifies the time interval in minutes between measurements. The registers of the DS1616 are eight bits wide, and so the maximum value that can be set is 255 minutes. For the RTC to work correctly, and so that a series of measurements can be initiated, the sample rate must be set to a value greater than or equal to one. When the battery is changed the sample rate is reset to zero; if the RTC is set but the sample rate not set to a value of at least one, the RTC will not operate properly.

Start Mission

This button initiates a sequence of measurements. The enabled channels and the sample rate should already have been set: incorrect settings will case a pop-up to appear. Real-time values of temperature and humidity will no longer be updated once per second, but rather at the preset sample rate.

Serial Number

Each DS1616 is factory-programmed with a unique serial number. When a save command is issued, this number is stored along with the measured data, so that the particular module that produced the data can be identified.

COMPONENTS LIST

Resistors:

R1,R7,R14,R15,R18 = 10kΩ
R2,R21 = 100kΩ
R3 = 47kΩ
R4 = 220Ω
R5 = 68kΩ
R6,R11,R13 = 10MΩ
R8 = 470kΩ
R9,R12 = 1MΩ
R10 = 150 kΩ
R16,R17,R19,R20 = 1kΩ
P1 = 250kΩ preset (vertical mounting)
P2 = 2MΩ preset (vertical mounting)

Capacitors:

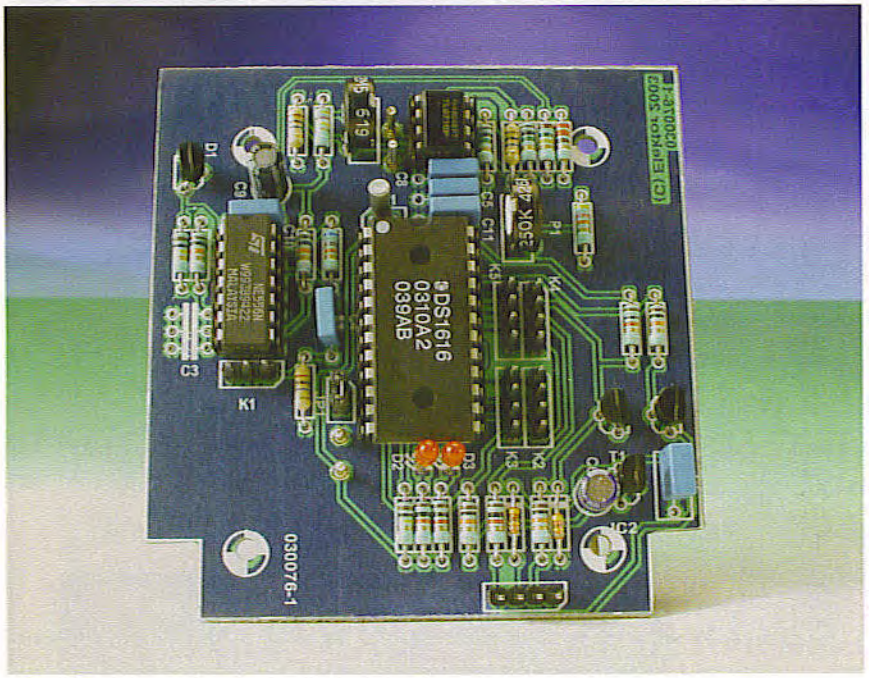
C1,C2,C3 = see text
C4,C5,C8,C10,C11 = 100nF
C6 = 22µF 16V radial
C7 = 330nF
C9 = 10µF 16V radial

Semiconductors:

D1 = LM385-2.5
D2= LED, red, 3mm, low-current
D3 = LED green, 3mm, low-current
D4,D5 = 1N4148
T1,T2 = BC547
IC1 = TS556
IC2 = 78L05
IC3 = MCP6041-I/P (Microchip) (Farnell # 396-8790)
IC4 = DS1616

Miscellaneous:

JP1 = pushbutton, 1 make contact
K1 = 3-way pinheader
Humidity sensor type HS1101 (www.humirel.com), available from Unitronic (www.unitronic.de)
K2-K6 = 4-way pinheader
BT1 = 3V Lithium cell
X1 = 32.768 kHz quartz crystal
BT2 = 2 UM-5 (AM-5) or AA batteries (depending on available enclosure)
9-way sub-D socket (female), angled pins, chassis mount
ABS enclosure with battery compartment (OKW size # 3 for AA cells, e.g. RS Components # 583-218)
PCB, order code **030076-1** (see Readers Service page)
Disk, Windows software, order code **030076-11** or Free Download



Temperature Thresholds

These threshold values set the temperature limits above or below which the alarm flag in the Status 1 register will be set, which in turn pulls the interrupt output ~~INT~~ low. This latter signal is available on K2 and K3 and can be used, for example, to trigger an acoustic warning signal. The 'Clear' button must be pressed to reset the alarm flag.

Temperature and Other Graphs

This window provides information about the measured temperature values (**Figure 7**). Sample 1 corresponds to the time given under *Mission started* @. This allows the date and time of each stored sample to be determined. In order not to waste CPU time needlessly, an automatic update feature is not provided. The graph can be updated by re-opening the window or by pressing the *Update* button.

Auto Scaling gives an overview of the series of temperature readings. The graph limits are no longer set at –40 °C and +80 °C, but are set to the lowest and highest temperature values stored in the data memory. The Save command stores the measured values on the local hard disk, with a user-selected path.

The Humidity, ADC1 and ADC3 plots are identical in terms of function and appearance. In future versions of the software the two spare channels will also be used.

Other Windows

The *ADC Channels* window can be called up under *ADC Channels/Show ADC Channels* in the main menu. It provides up-to-date readings from the analogue channels. Disabled inputs are displayed in grey, as shown on the right in **Figure 8**. Threshold values can also be set for the analogue inputs: these operate in the same way as the temperature thresholds.

The *Alarm Settings* window (**Figure 9**) includes the various settings relating to the RTC (real-time clock).

The RTC can be set to the PC's system time using *Set*. The remaining settings can be used, for example, to implement a time switch function. An interrupt on ~~INT~~ is generated when the RTC value agrees with the preset alarm time. RTC and alarm settings can only be changed while the DS1616 is not busy taking a sequence of readings.

Under *Settings/Performance* is a facility for setting to any desired value the timer period which governs the regular reading of data from all the sensors and analogue inputs. The greater this value, the greater the interval between samples, and the correspondingly smaller the amount of CPU time consumed by the software. An optimum value for the timer period can be found using the *System Monitor* (a Win XP utility) to accurately measure the CPU load and performance. PCs and laptops that have plenty of memory and processor power should have no problem with a timer interval of one second. The functions of the *System Monitor* are described in more detail in the help.

Operation

The climate logger is connected to a free serial port on the PC or notebook using an ordinary serial cable (straight-through, **not** a null-modem cable). The first time the logger software is run the selected COM port must be specified; this setting is stored and need not

Calculating the battery life

The type CR1620 backup battery (3 V, 60 mAh) supplies only the DS1616 and its internal temperature sensor. The humidity measurement circuit consumes rather more current and so is supplied from two AA cells to give a reasonable battery life. The life of the coin cell depends on the selected sample rate; in order to calculate the battery life, its capacity must simply be divided by the average current consumption of the circuit (I_{avg}).For example, with a sample period of 60 s we have:

$$\text{Battery life} = \text{battery capacity} / I_{avg}$$

where the average current is given by

$$I_{avg} = [t_{tc} \cdot i_{tc} + (T - t_{tc}) \cdot i_{OSC}] / T$$

where t_{TC} is the duration of one measurement (150 ms), i_{TC} is the current drawn while carrying out a temperature measurement (0.5 mA), i_{OSC} is the quiescent current consumption (450 nA), and T is the sample period (60 s).

The calculated battery life is approximately four years.

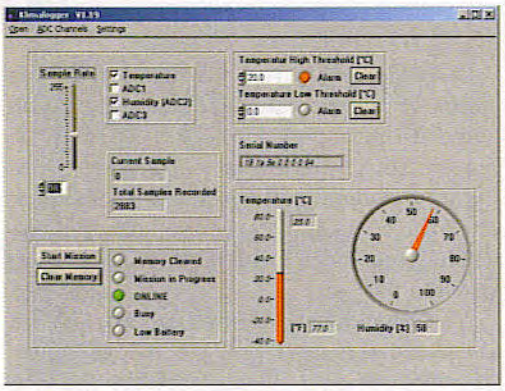


Figure 6. All the important parameters are shown in the main window.

be entered again unless the logger is connected to a different COM port.

When first powered up a new DS1616 has its RAM filled with 0xFFs. When the climate logger is connected to the PC for the first time, the RTC time and a (sensible) sample rate must be set. This must also be done whenever the device's backup battery voltage is interrupted (i.e., when BT2 is changed). Until the sample rate is set, the PC will read a measured value every second, and the display will be updated every second.

While the data logger is connected to the PC, the sample rate and other parameters

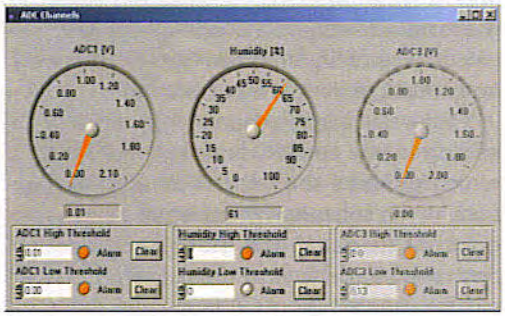


Figure 8. The three external analogue inputs are shown under *ADC Channels*.

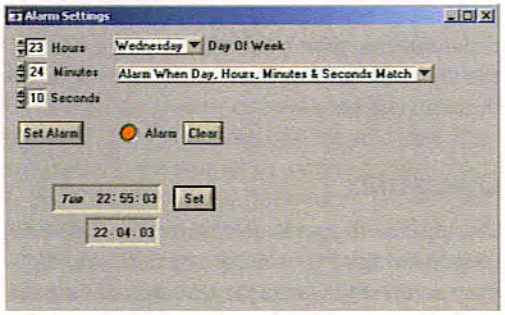


Figure 9. Using the alarm settings the Climate Logger can be used as a time switch.

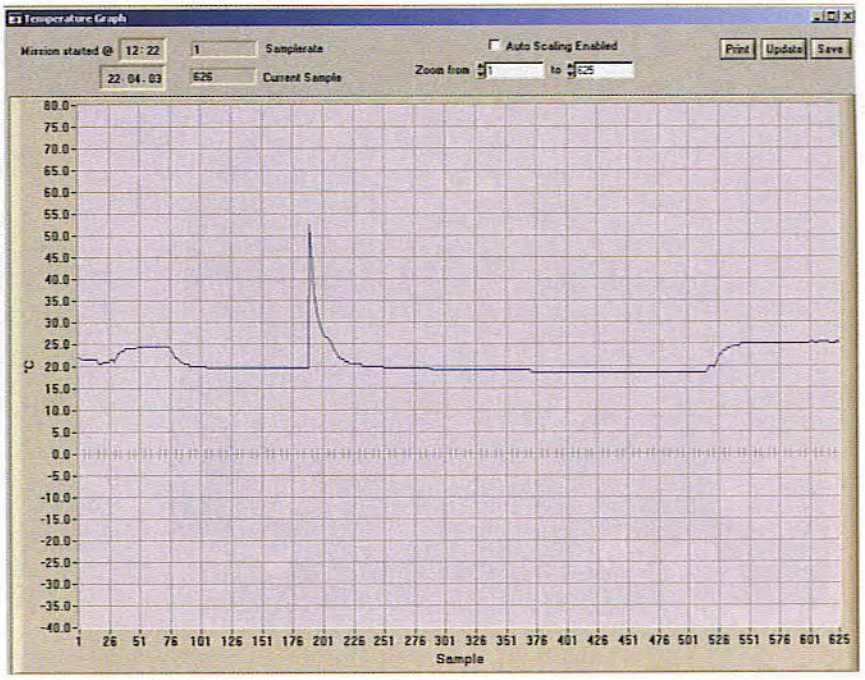


Figure 7. The series of measured values (temperature, humidity, or either of the two spare inputs) can be displayed as a graph or as a table.

can be set and adjusted as desired for the next mission. When the data logger is disconnected from the PC it retains these settings and operates in standalone mode. The settings will only be lost if the backup battery supply to the DS1616 is interrupted.

In the most recent version of the software available as we went to press (v1.23), a mission can also be initiated using the pushbutton connected across JP1. This is done as follows. First configure the sample rate, enabled channels and so on as described under 'Software' above. Then click on 'Enable External Start' and clear the memory contents: the 'Memory Cleared' indicator will appear on the screen. The logger can now be disconnected from the PC and taken to the location where measurements are to be made. To initiate the mission, it is now simply necessary to press the pushbutton for at least 0.5 seconds; data recording will then begin.

Measurements can also be initiated using the pushbutton while the logger is still connected to the PC. It is not necessary to shut down the program: it can remain running and will check whether a mission has been initiated.

If any of the settings (enabled channels or sampling rate) is changed after 'Enable External Start' has been clicked, the 'Enable External Start' feature is automatically reset. 'Enable External Start' should only therefore be clicked when all the needed settings have been configured, since it is at this point that the selected sample rate and channel selections are transferred to the DS1616. If any settings are subsequently changed on the PC, they will not be sent to the DS1616, and so the configuration of the logger will not match what is displayed on the screen.

(030076-1)

Free Downloads

Windows software. File number: **030076-11.zip**.

PCB layout in PDF format. File number: **030076-1.zip**.

www.elektor-electronics.co.uk/dl/dl.htm,
select month of publication.