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Note

Portable computer-based temperature programmer

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This project was initiated by the need for a temperature programmer to replace the electro-mechanical unit in an older gas chromatograph. The original unit needed replacement parts that were no longer available. Modern stand-alone controllers with linear temperature programming capability suitable for gas chromatography (GC) are not readily available. In this note we describe our approach to the problem using readily available components.

HARDWARE

A lap type computer (Radio Shack TRS80 Model 100) was chosen as a trade-off between cost and development time. It also offered easy modifications of the control program if required at a later time.

An overview of the circuit is shown in Fig. 1. The thermocouple voltage is amplified (nominal 10 mV/°C) and cold junction compensated by the AD595. This voltage is then digitised by the 7109 12-bit A/D converter. The digital output is sent via the 6403 UART to the computer's RS232C serial port as two 8-bit bytes. Since the 7109 and the 6403 were designed to work together this transfer is easily accomplished using the handshake lines provided.

An 8-bit data word (0-255), calculated according to the algorithm discussed below, controlled the mark/space ratio of the 7240 (programmable timer), which in turn controlled the column oven triac. At the end of each cycle the data input of the 7240 is reset to zero.

The timing for the 7109, the 6403 and the 7240 was derived from a 2.4576-MHz crystal connected to the UART. A divider chain was used to derive the 51.2-kHz signal required by the A/D converter and the 1-Hz signal for triggering the A/D converter, resetting the programmable timer and initiating data transmission to the computer at 9600 baud.

The design freed the computer from any time keeping requirements. This greatly simplified the software and also made it fail-safe if the computer is inadvertently turned off.

The cost of parts for the interface was approximately NZ$ 250. The time for design and construction was less than three weeks.

The best control, as determined by the reproducibility of the chromatogram of a test sample, was obtained with a bare thermocouple suspended in air near the column.

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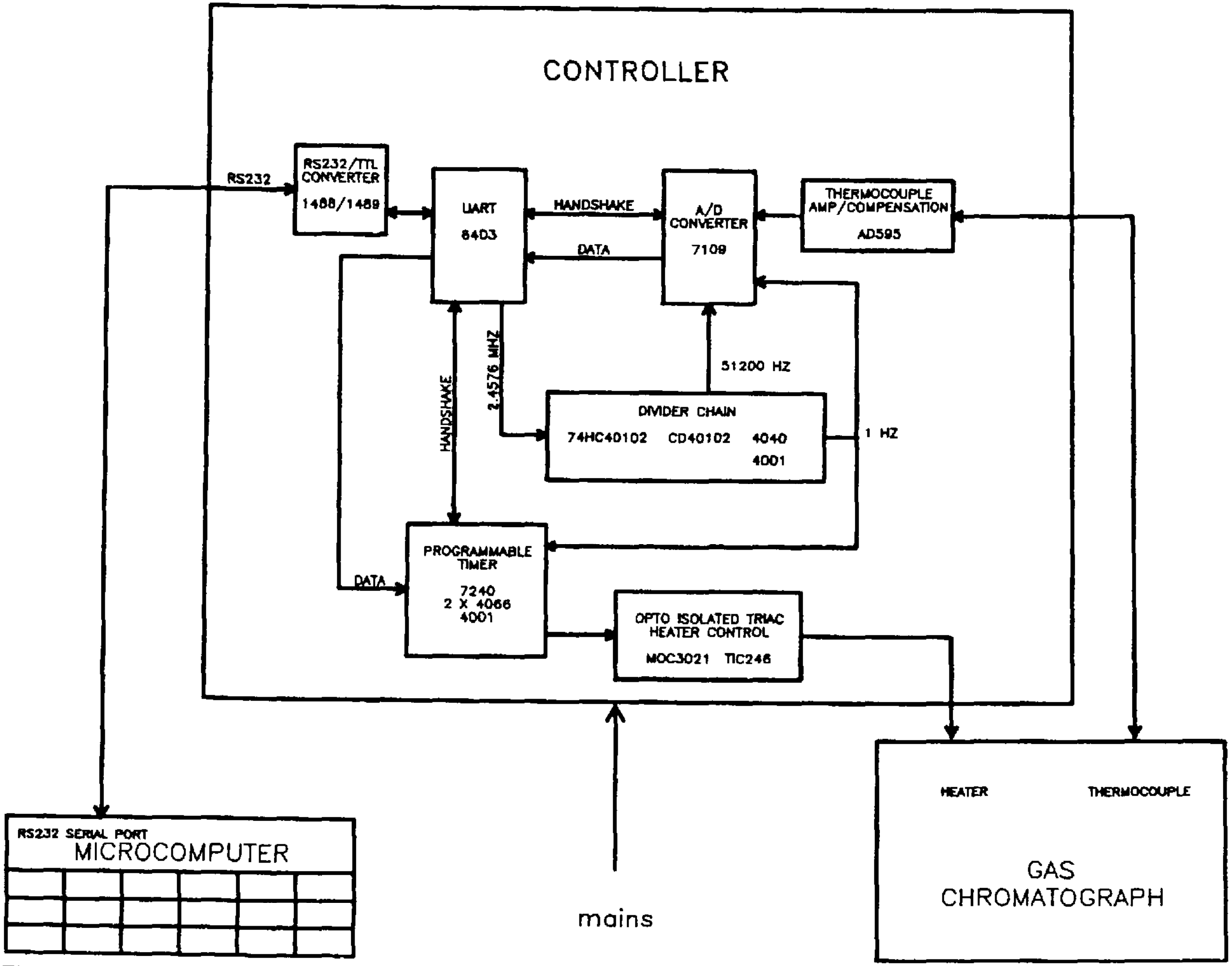

Fig. 1. Overview of the interface. The programmable timer (ICM7240), A/D converter (ICL 7109) and UART (ICM6403) are from Intersil (Cupertino, CA, U.S.A.), the compensated thermocouple amplifier (AD595) is from Analog Devices (Norwood, MA, U.S.A.). The computer used was a Radio Shack TRS80 Model 100.

SOFTWARE

The program, written in BASIC, included a machine code subroutine in order to bypass a feature of the Model 100's BASIC[1]. The input of data equivalent to decimal 26 on the RS232 port is interpreted as an end-of-file. A short machine code subroutine called from BASIC overcame this problem. We found that the ROM interrupt that reads the RS232 port into the internal buffer in real time and the routine that reads this buffer do not check for end-of-file. The machine code subroutine calls the internal ROM routine to read the RS232 buffer 2 bytes at a time (representing the high and low order bytes of the A/D converter data word) and places them in a BASIC integer (16-bit) variable for use by the BASIC program.

The Model 100's BASIC interrupt system is used to determine when temperature data are available for processing. This is not a real-time interrupt, it appears that the RS232 buffer is polled at the end of a BASIC line. With a long BASIC line involving slow functions, *e.g.* printing to the screen, the delay could run into hundreds of milliseconds. This variation in response time could cause data to be supplied to the 7240 timer before the previous cycle has finished. If this happened, the new data would be ignored and the cycle missed.

Temperature control is based on the proportional plus integral plus rate (PID) algorithm[2]. The proportional, integral and differential gains were set empirically. The algorithm calculates the required power level, which is then converted to a number proportional to the power required to maintain the temperature at the set point. The number is limited to range from 0 to 253 representing 0 to 99% of maximum power. Although theoretically the input to the 7240 could range from 0 to 255 (0 to 100%), we have limited the output to a maximum of 253 because of the "interrupt" latency mentioned above. With the GC instruments (Varian Models 1520 and 2700) used this is immaterial since the power demand at equilibrium is less than 50% of maximum, even at 300°C and at 10°C/min. In fact the high wattage of the heater (1.5 kW) necessitated some modification of the PID algorithm to minimise the overshoot during the initial heating up. When the temperature is within 5°C of the set-point power is only applied when the rate of rise of temperature is less than or equal to zero. Once the set-point has been reached normal PID action is resumed.

The program as implemented allows for two temperature ramps and isothermal periods at the start, between ramps, and at the end of temperature programming. The temperature programming parameters may be changed at any time during the run. Status information, such as run time, set point and actual temperature, is displayed on the screen. It would be a simple task to incorporate additional ramps and other control features if desired.

CONCLUSION

The circuit described here presents a cost effective approach to upgrading an older GC instrument in which the electro-mechanical analogue temperature controller has become unreliable or inadequate. Since the program is written in BASIC for a microcomputer, custon features, *e.g.* starting of integrators and valve switching, could be easily incorporated.

During 12 months of use with capillary columns the reproducibility of the retention times for various samples was found to be similar to that obtained on a HP5790 gas chromatograph (± 0.1 min).

The circuit diagram and a program listing are available from the authors.

REFERENCES

1 J. A. Blackburn, S. Vik, H. Saunderson and M. Stone, *Rev. Sci. Instrum.*, 55 (1984) 1862.
2 C. L. Pomernacki, *Rev. Sci. Instrum.*, 48 (1977) 1420.