

Contents

1	Introduction	1
1.1	How to use this book	3
1.2	Chapter summary	3
2	Instrumentation structures and using the IBM-PC	5
2.1	First program and graphs	6
Ex 2.1.1	Starting out	6
Ex 2.1.2	Saving programs and writing text files	7
Ex 2.1.3	Simple graphing	9
2.2	Addresses and data, RAM and ROM	10
3	Thermistor experiments	12
3.1	Using the ADC	12
Ex 3.1.1	Using the ADC	13
Ex 3.1.2	Programming the ADC	15
3.2	ADCs	15
Ex 3.2.1	ADC and sampling	16
Ex 3.2.2	Audio digital sampling	18
3.3	Thermistor resistance vs. temperature characteristics	19
Ex 3.3.1	Thermistor mathematical models	20
Ex 3.3.2	Specific heat and power	21
Ex 3.3.3	Lag time	24
Ex 3.3.4	Thermistor resistance measurement	24
Ex 3.3.5	Data arrays	25
3.4	Making and retrieving sequential data files	25
Ex 3.4.1	WriteArrays procedure	25
Ex 3.4.2	Program TestWrite	26
Ex 3.4.3	ReadArrays procedure	27
Ex 3.4.4	Program TestRead	28
Ex 3.4.5	Temperature and thermistor resistance data file	29
3.5	Plotting the experimental data	29
Ex 3.5.1	Thermistor data plot	29
Ex 3.5.2	Logarithmic plot	29
Ex 3.5.3	Linearized thermistor data plot	30
3.6	A least squares fit to the data	30
Ex 3.6.1	Least squares fit to data	31
Ex 3.6.2	Plot of residuals	32

Contents

3.7	Data modeling	32
3.8	Errors in data and parameters	35
	Ex 3.8.1 Errors in thermistor data	36
3.9	Digital signal processing	36
3.10	Controlling computer output ports	37
	Ex 3.10.1 Square wave output	38
	Ex 3.10.2 Square wave output on PA3	39
3.11	Port and Mem statements	39
3.12	Using a HEXFET to control the heater	39
	Ex 3.12.1 Controlling the HEXFET	40
	Ex 3.12.2 Temperature controller	41
	Ex 3.12.3 Temperature controller with hysteresis	41
4	Timing	43
4.1	Timing loops	43
	Ex 4.1.1 Timing loops	43
4.2	Stepping motors	44
	Ex 4.2.1 Single step of stepping motor	44
	Ex 4.2.2 Maximum stepping rate	46
	Ex 4.2.3 Truncation errors	47
	Ex 4.2.4 Positioner	47
4.3	Number systems	48
	Ex 4.3.1 LED binary number display	50
4.4	Using the internal clock	52
	Ex 4.4.1 Reading the internal clock	53
	Ex 4.4.2 A stopwatch	53
	Ex 4.4.3 A beeper	53
5	Thermal diffusion	54
5.1	Heat flow equation	54
	Ex 5.1.1 Impulse heat diffusion solution	55
	Ex 5.1.2 Graphing the heat diffusion equation	56
5.2	Numerical integration of the heat flow equation	57
	Ex 5.2.1 Integration algorithm	58
5.3	Experimental setup and program development	58
	Ex 5.3.1 Heat impulse to rod	59
5.4	Voltage amplifier	60
	Ex 5.4.1 Amplifier check	61
	Ex 5.4.2 Heat flow real-time plot	61
5.5	Data analysis	62
	Ex 5.5.1 The thermal conductivity and specific heat of copper	63
	Ex 5.5.2 Time shift of heat flow data	64
	Ex 5.5.3 Least squares fit to the heat flow data	64
5.6	Conduction, convection, and radiation	64
	Ex 5.6.1 Estimation of convective and radiative losses	65

Contents

ix

6 IBM-PC architecture and assembly language programming	66
6.1 Inside the IBM-PC	66
6.2 The 8088 microprocessor	68
6.3 Writing machine language programs	70
Ex 6.3.1 A simple program in DEBUG	70
Ex 6.3.2 Memory dump	74
Ex 6.3.3 Writing a binary file	74
Ex 6.3.4 Machine language square waves	75
6.4 Compiled Pascal and Inline	75
Ex 6.4.1 Compiled Turbo Pascal	75
Ex 6.4.2 Example Inline program	78
Ex 6.4.3 Inline square wave program	79
6.5 Operation of a DAC	79
Ex 6.5.1 DAC sawtooth wave	80
Ex 6.5.2 DAC sine wave	80
6.6 Indexed addressing	80
Ex 6.6.1 Indexed Pascal and DEBUG programs	80
Ex 6.6.2 DAC output Inline	83
6.7 An X-Y plotter	83
Ex 6.7.1 Lissajous figures on DAC X-Y plotter	83
6.8 Boolean algebra	84
Ex 6.8.1 AND	85
Ex 6.8.2 OR	86
Ex 6.8.3 XOR	86
Ex 6.8.4 NOT	87
Ex 6.8.5 Turbo Pascal Boolean expressions	87
6.9 Branching instructions	87
Ex 6.9.1 Masking and branching	88
6.10 Subroutines and the use of the stack	89
Ex 6.10.1 CALL	91
6.11 ADC EOC	91
Ex 6.11.1 ADC maximum sample rate	91
7 Viscosity measurement	92
7.1 Force required to move a solid body through a fluid	92
Ex 7.1.1 Stokes' law	96
Ex 7.1.2 Approach to terminal velocity	96
7.2 The experimental apparatus	97
Ex 7.2.1 Cadmium sulfide cell resistance and voltage changes	98
7.3 Using the 8253 timer	99
Ex 7.3.1 Speed of a sphere in air	99
Ex 7.3.2 Using the 8253 timer 0	101
Ex 7.3.3 Interrupt protection	101
Ex 7.3.4 Inline timer 0 access	101
Ex 7.3.5 Measuring ADC sample speed	102

Contents

7.4	Subtraction and addition	102
Ex 7.4.1	Double precision integer subtraction	103
7.5	The viscometer	104
Ex 7.5.1	Light beam sensing and timing	104
Ex 7.5.2	The viscosity of glycerine	104
Ex 7.5.3	The wall effect	105
Ex 7.5.4	Temperature variation of the viscosity of glycerine	106
Ex 7.5.5	The viscosity of aqueous solutions of glycerine	106
8	Interrupts	108
8.1	Interrupts and the CPU	108
Ex 8.1.1	Using the TOD software interrupt	111
Ex 8.1.2	Resetting the TOD interrupt	113
8.2	Writing a hardware interrupt ISR	113
Ex 8.2.1	JBE 1 Hz interrupts	115
8.3	Serial data communication and 8251 UART	116
Ex 8.3.1	Simple UART programming	119
8.4	Serial interrupt processing	119
Ex 8.4.1	Serial interrupt program	119
9	Other topics	121
9.1	Hardware for data acquisition and control	121
9.2	Parallel data communication	121
Ex 9.2.1	Parallel communication	123
9.3	DOS and BIOS function calls	123
9.4	EPROM and EEPROM	125
9.5	Sensors and transducers	126
9.6	Software for data acquisition and control	126
9.7	Where to go from here	127
Appendix A	Laboratory materials and sources	128
Appendix B	Graphing programs and disk configuration	135
Appendix C	IBM-PC memory map	137
Appendix D	Connections and logic of the ADC	140
Appendix E	8255 Programmable Peripheral Interface data sheets	142
Appendix F	Solution for heat flow in one dimension	167
Appendix G	Finite impulse heat flow in a rod	170
Appendix H	8088 Microprocessor data sheets	173
Appendix I	8253 Programmable interval timer data sheets	204
Appendix J	8250/8251 Programmable Communication Interface	216
Appendix K	Bibliography and sources	240
Index		243