

Contents

1	Operational Amplifier and Analog Signal Processing Circuits: A	
	Revision	1
1.1	Introduction	1
1.2	Voltage Follower Circuit	2
1.3	Inverting Amplifier	3
1.4	Sign Changer	3
1.5	Phase Shifter	4
1.6	Inverting Summing Amplifier	4
1.7	Non-inverting Amplifier	4
1.8	Non-inverting Summing Amplifier	5
1.9	Difference Amplifier	6
1.10	Current to Voltage (I-V) Converter	7
1.11	Integrator	7
1.12	Differentiator	9
1.13	Comparators and Schmitt Triggers	9
1.14	Logarithmic Amplifier	11
1.15	Exponential Amplifier	13
1.16	Single-Pole Filters	13
1.17	Double-Pole Filters	15
1.18	Band-Pass and Band-Stop Filters	16
1.19	Oscillator Circuits	18
2	Introduction to Silicon Labs C8051F020 Microcontroller	21
2.1	Introduction	21
2.2	CIP-51	21
2.3	C8051F020 System Overview	22
2.4	Memory Organization	24
2.4.1	Program Memory	24
2.4.2	Data Memory	25
2.4.3	Stack	25
2.4.4	Special Function Registers (SFRs)	26
2.5	I/O Ports and Crossbar	27
2.6	12-Bit Analog to Digital Converter	28

2.7	8-Bit Analog to Digital Converter	29
2.8	Digital to Analog Converters	30
2.9	Analog Voltage Comparators	32
2.9.1	Enable/Disable Comparator	33
2.9.2	Programmable Hysteresis	33
2.9.3	Comparator Output and Interrupt.....	34
2.10	Voltage Reference	35
2.10.1	REF0CN: Reference Control Register	36
2.11	Programmable Counter Array (PCA)	37
2.11.1	PCA Counter/Timer and Timebase Selection	38
2.11.2	Operation Modes and Interrupts	39
2.11.3	Edge-Triggered Capture Mode	41
2.11.4	Software Timer (Compare) Mode.....	42
2.11.5	High Speed Output Mode	42
2.11.6	Frequency Output Mode	43
2.11.7	8-Bit Pulse Width Modulator Mode.....	44
2.11.8	16-Bit Pulse Width Modulator Mode.....	46
3	C Programming for Silabs C8051F020 Microcontroller.....	49
3.1	Introduction	49
3.2	Register Definitions, Initialization and Startup Code	49
3.3	Basic C Program Structure	50
3.4	Programming Memory Models.....	50
3.4.1	Overriding the Default Memory Model.....	51
3.4.2	Bit-Valued Data	52
3.4.3	Special Function Registers.....	52
3.4.4	Locating Variables at Absolute Addresses	53
3.5	C Language Operators and Control Structures	53
3.5.1	Relational Operators	53
3.5.2	Logical Operators	54
3.5.3	Bitwise Logical Operators	54
3.5.4	Compound Operators.....	55
3.5.5	Making Choices	56
3.5.6	Repetition.....	57
3.5.7	Waiting for Events.....	58
3.5.8	Early Exits	58
3.6	Functions	59
3.6.1	Standard Function – Initializing System Clock	59
3.6.2	Memory Model Used for a Function.....	60
3.7	Interrupt Functions.....	60
3.7.1	Timer 3 Interrupt Service Routine	60
3.7.2	Disabling Interrupts before Initialization.....	61
3.7.3	Timer 3 Interrupt Initialization	61
3.7.4	Register Banks	62
3.8	Reentrant Functions	62

3.9	Pointers	63
3.9.1	A Generic Pointer in Keil™ C	63
3.9.2	Memory Specific Pointers	63
3.10	Summary of Data Types	64
4	Design Issues of Microcontroller Interfacing.....	67
4.1	Introduction	67
4.2	Open-Collector Configuration	67
4.3	Protection of Microcontroller from Over-Voltage	68
4.4	Switching Inductive Load and Diode Protection	71
4.5	Potential Divider for Feedback Voltage	72
4.6	Interfacing a Digital Signal	75
4.7	Interfacing an Analog Signal	78
4.8	Discussions	81
5	Embedded Microcontroller Based DC Motor Control: A Project Based Approach.....	83
5.1	Introduction	83
5.2	Description of the Problem	84
5.3	Motivation of the Project	86
5.4	Basic Theory of the Project	87
5.4.1	Speed Control Using Pulse Width Modulation (PWM).....	87
5.4.2	Generating PWM Signal	88
5.4.3	PWM Frequency: Timer 0 Reload Value	89
5.4.4	Varying the PWM Duty Ratio	90
5.4.5	Measuring Motor Speed and Closed Loop Control	91
5.4.6	Measuring Actual Motor Speed	91
5.4.7	Calculating the Value of K	92
5.4.8	Counting N (Number of Ticks for One Revolution)	92
5.4.9	Setting Motor Reference Speed	93
5.4.10	Recording Transient Behavior of Motor.....	93
5.4.11	Displaying Actual Motor Speed as an Analog Voltage on Oscilloscope.....	94
5.5	Guidelines to the Students	95
5.6	Outcome of the Project	99
6	Embedded Microcontroller Based Switched Mode Power Supply: A Student Project.....	103
6.1	Introduction	103
6.2	Description of the Project: Design of Power Supply	104
6.2.1	Specifications of the Problem	104
6.2.2	Objectives	104
6.2.3	Experiment and Comments.....	104
6.2.4	Guidance on the Implementation	105
6.2.5	Experiment with Open-Loop Power Circuit	105

6.2.6	Design and Implementation of the Control Circuit.....	105
6.2.7	Experiment with the Implemented Model	105
6.2.8	Submission Requirements.....	105
6.3	Design Process.....	106
6.4	Design of a Closed Loop Controller	108
6.4.1	Oscillator.....	108
6.4.2	Op Amp	109
6.4.3	Comparator	109
6.4.4	NAND Block	109
6.4.5	Power Circuit	109
6.5	Implementation of an Embedded Microcontroller Based Switched Mode Power Supply	112
6.6	Comments.....	116
6.6.1	Design Issues	116
6.6.2	Challenges of the Project Implementation	116
6.7	Conclusions	117
A6	Appendix.....	117
A6.1	Microcontroller Setup	117
A6.2	Reference Voltage.....	118
A6.3	Generation of 100 kHz PWM	118
A6.4	Feedback Voltage.....	118
A6.5	Implementation of PWM	118
A6.6	Control Loop.....	119
A6.7	Listing of the Complete Program Code	119
A6.8	Working Waveforms.....	124
7	Embedded Microcontroller Based Magnetic Levitation.....	127
7.1	Introduction	127
7.2	Background and Motivation	127
7.3	Hybrid Active Magnetic Bearing.....	129
7.3.1	Displacement Sensor.....	129
7.3.2	Permanent Magnet	129
7.3.3	Electromagnet and Force Relationship	131
7.4	Design of Control System.....	133
7.4.1	PID Controller	133
7.4.2	Analog Control System.....	134
7.4.3	Results from the Controller.....	137
7.5	Microcontroller Based Control System	141
7.5.1	Microcontroller Code.....	143
7.5.2	Results of the Microcontroller Based Control	146
7.6	Conclusions	148
A7	Appendix.....	149
A7.1	Microcontroller Code Listing.....	149
8	Embedded Microcontroller Based Fireworks Detonation System.....	157
8.1	Introduction	157

8.2	Preliminary Version of the System	158
8.3	Requirements	160
8.4	Design and Implementation	160
8.4.1	Overview of Control Software	160
8.4.2	Manual Interface	161
8.4.3	Scripting Interface	162
8.4.4	Designer Interface	164
8.5	Remote Firing Module	164
8.5.1	Overview and Methodology	164
8.5.2	Electric Matches	165
8.5.3	User Interface	166
8.5.4	Operational Modes	167
8.5.5	Wireless Network	168
8.5.6	Power Supply	168
8.5.7	Battery Charger	169
8.5.8	Firing and Testing	170
8.6	Central Control Circuit	171
8.6.1	LCD Control Circuit	172
8.6.2	RF Modem Control Circuit	173
8.6.3	IO Control Circuit	175
8.7	Developed Hardware	176
8.8	Firmware	179
8.8.1	Overview	179
8.8.2	Communications	180
8.8.3	Command and Response Set	181
8.8.4	Event System	182
A8	Appendix	184
9	Embedded Microcontroller Based Non-destructive Seafood Inspection System	199
9.1	Introduction	199
9.2	Working Principle of Interdigital Sensors	199
9.3	Sensing System for Seafood Inspection	203
9.4	Interfacing to Microcontroller	204
9.5	Initialization of Important Parts of Microcontroller	204
9.6	Electronics and Signal Processing Circuit for the Low Cost Sensing System	207
9.7	Smooth Sine Wave Generation	209
9.8	Signal Rectification and Amplification	210
9.9	Calibration, Sensitivity Threshold and Signal Definitions	210
9.10	Prototype of Seafood Inspection Tool (SIT)	212
9.11	Conclusion	213