



**UCF Stormwater Academy  
Rain Simulator**

**Group: 10**

**Luke Falls  
Adam Cutting  
David Levy  
Brenda Garcia**

**December 9<sup>th</sup>, 2011  
Fall 2011**

## TABLE OF CONTENTS

<b>1.0 EXECUTIVE OVERVIEW .....</b>	<b>1</b>
1.1 PROJECT SUMMARY .....	2
1.2 PROJECT DESCRIPTION .....	3
1.3 GOALS AND OBJECTIVES .....	3
1.4 REQUIREMENTS & SPECIFICATIONS .....	5
1.5 EXISTING SIMILAR PROJECTS .....	6
1.6 TEAM INTRODUCTION .....	7
<b>2.0 STRATEGIC COMPONENTS.....</b>	<b>10</b>
2.1 STEPPER MOTORS.....	10
2.1.1 <i>Permanent Magnet Stepper Motor</i> .....	14
2.1.2 <i>Variable Reluctance Stepper Motor</i> .....	14
2.1.3 <i>Hybrid Stepper Motor</i> .....	16
2.1.4 <i>Motor Winding Configurations</i> .....	19
2.2 STEPPER MOTOR DRIVER CIRCUITS .....	21
2.2.1 <i>Unipolar Driver Circuits</i> .....	21
2.2.2 <i>Bipolar Driver Circuits</i> .....	23
2.2.3 <i>Motor Driver – DRV8432</i> .....	25
2.3 USER INTERFACE.....	30
2.3.1 <i>Light Emitting Diode Display</i> .....	30
2.3.2 <i>Plasma Display</i> .....	31
2.3.3 <i>Liquid Crystal Display</i> .....	31
2.3.4 <i>Keypad</i> .....	32
2.4 MICROCONTROLLER.....	33
2.4.1 <i>I/O, Timers, and Serial Communication</i> .....	35
2.4.2 <i>ADCs and Special Features</i> .....	36
2.4.3 <i>Programming Methods and Pricing</i> .....	36
2.5 MSP430F5435 MICROCONTROLLER.....	37
2.5.1 <i>Unified Clock System</i> .....	37
2.5.2 <i>Universal Serial Communication</i> .....	39
2.5.3 <i>Real Time Clock</i> .....	44
2.5.4 <i>Built in Timer Operation</i> .....	44
2.6 POWER SUPPLY.....	47
2.6.1 <i>Regulated vs. Unregulated Design</i> .....	47
2.6.2 <i>Linear vs. Switching Power Supply</i> .....	48
2.7 SPRAY NOZZLES.....	49
2.8 TRANSMISSION LINES.....	50
2.9 OPTIONAL WIRELESS INTEGRATION .....	52
2.9.1 <i>The IEEE 802.11 Wi-Fi Standard</i> .....	53
2.9.2 <i>Bluetooth Wireless Technology</i> .....	55
2.9.3 <i>Zigbee Wireless Technology</i> .....	56
2.9.4 <i>Siteplayer &amp; Wi-Fi Joint Integration</i> .....	58
2.9.5 <i>Rain Gauge Data Logging</i> .....	58

2.9.6	<i>Rain Gauge Design</i> .....	60
2.10	PROGRAMMING INTERFACE.....	60
2.10.1	<i>JTAG</i> .....	60
2.10.2	<i>Spy-Bi-Wire</i> .....	62
2.10.3	<i>Bootstrap Loader</i> .....	63
2.11	PROTECTION FROM THE ELEMENTS.....	64
2.11.1	<i>Enclosure</i> .....	64
2.11.2	<i>Conformal Coating</i> .....	65
2.11.3	<i>Heat Dissipation</i> .....	66
<b>3.0</b>	<b>SMALL-SCALE PROTOTYPE</b> .....	<b>68</b>
3.1	SMALL-SCALE MODEL MICROCONTROLLER.....	69
3.2	STEPPER MOTORS.....	75
3.3	STEPPER MOTOR DRIVERS.....	77
3.4	POWER SUPPLY.....	84
3.5	USER INTERFACE.....	87
3.6	SOFTWARE FOR THE SMALL-SCALE MODEL.....	88
3.7	FINAL BUILD OF THE SMALL-SCALE MODEL.....	89
<b>4.0</b>	<b>FINAL DESIGN</b> .....	<b>91</b>
4.1	MICROCONTROLLER.....	91
4.2	MOTOR DRIVERS.....	91
4.3	POWER SUPPLY.....	92
4.3.1	<i>Transformer</i> .....	94
4.3.2	<i>Full-Wave Bridge Rectifier</i> .....	95
4.3.3	<i>Capacitor</i> .....	96
4.3.4	<i>Stepper Motor Supply Design Summary</i> .....	97
4.3.5	<i>Control Voltage Power Supply</i> .....	98
4.4	OVER-TRAVEL SENSORS.....	100
4.5	WIRELESS RAIN GAUGE.....	101
4.6	SOFTWARE DESIGN.....	104
4.6.1	<i>Software State-Machine</i> .....	104
4.6.2	<i>Reading User Input</i> .....	104
4.6.3	<i>Port Assignments</i> .....	106
4.6.4	<i>Motor Controller – PWM Signals</i> .....	107
4.6.5	<i>Real-Time Clock</i> .....	107
4.6.6	<i>Interrupt Handling</i> .....	108
4.6.7	<i>Serial Communication</i> .....	109
4.6.8	<i>JTAG – MSP430 Devices</i> .....	109
4.6.9	<i>JTAG – MSP-FET430UIF</i> .....	112
4.7	USER INTERFACE DESIGN.....	114
4.7.1	<i>LCD – PC2004-A</i> .....	114
4.7.2	<i>Display Driver – KS0066U</i> .....	115
4.7.3	<i>Water Resistant Keypad – 1K12T103</i> .....	117
4.7.4	<i>Display Bezel</i> .....	119
4.8	PRINTED CIRCUIT BOARD.....	120
4.8.1	<i>Conformal Coating – TechSpray 2106</i> .....	122

4.9 THERMAL DESIGN .....	123
4.9.1 <i>Cooling System</i> .....	123
4.9.2 <i>Heat-Sink</i> .....	125
<b>5.0 TESTING PROCEDURES.....</b>	<b>126</b>
5.1 RAIN NOZZLE FLOW .....	126
5.2 STEPPER MOTOR POSITION .....	126
5.3 RAIN INTENSITY .....	129
5.4 SOFTWARE.....	129
5.5 POWER SUPPLY.....	130
5.6 THERMAL .....	130
5.7 TRANSMISSION LINE AND CONNECTORS.....	131
<b>6.0 SYSTEM OPERATION.....</b>	<b>131</b>
<b>7.0 ADMINISTRATIVE CONTENT .....</b>	<b>133</b>
7.1 FINANCING AND BUDGET .....	133
7.2 DONORS AND FUNDING .....	136
7.3 PROJECT PLANNING.....	138
<b>8.0 EXECUTIVE CONCLUSION.....</b>	<b>138</b>

# List of Figures and Tables

Figure 1.1a .....	2
Figure 1.5a .....	6
Figure 1.5b .....	6
Figure 1.6a .....	7
Figure 1.6b .....	8
Figure 1.6c .....	9
Figure 1.6d .....	10
Figure 2.1a .....	12
Figure 2.1b .....	13
Figure 2.1.2a .....	15
Figure 2.1.3a .....	17
Figure 2.1.4a .....	19
Table 2.1.4b .....	21
Figure 2.2.1a .....	22
Figure 2.2.2a .....	24
Table 2.2.3a .....	26
Table 2.2.3b .....	30
Table 2.4.1a .....	35
Table 2.4.2a .....	36
Table 2.4.3a .....	36
Figure 2.5.2a .....	42
Figure 2.5.2b .....	43
Table 2.5.4a .....	45
Table 2.5.4b .....	47
Figure 2.8a .....	50
Table 2.8b .....	51
Figure 2.9a .....	53
Figure 2.9.1a .....	54
Figure 2.10.1a .....	61
Figure 3.1a .....	70
Figure 3.1b .....	74
Table 3.1c.....	74
Figure 3.1d .....	75
Table 3.2a .....	76
Figure 3.2b .....	76
Figure 3.3a .....	79
Figure 3.3b .....	82
Table 3.3c.....	83
Figure 3.3d .....	83
Figure 3.4a .....	85
Table 3.4b .....	86
Figure 3.4c .....	86
Figure 3.5a .....	87
Table 3.5b .....	88

Table 3.7a .....	90
Figure 3.7b .....	90
Figure 4.2a .....	92
Figure 4.3a .....	93
Table 4.3.1a .....	95
Table 4.3.2a .....	96
Table 4.3.3a .....	97
Figure 4.3.4a .....	98
Figure 4.3.5a .....	100
Table 4.5a .....	101
Figure 4.5b .....	103
Figure 4.6.1a .....	104
Figure 4.6.2a .....	105
Figure 4.6.3a .....	106
Figure 4.6.4a .....	107
Figure 4.6.6a .....	108
Figure 4.6.7a .....	109
Figure 4.6.8a .....	111
Figure 4.6.8b .....	112
Figure 4.6.9a .....	113
Table 4.7.1a .....	115
Figure 4.7.2a .....	117
Figure 4.7.3a .....	118
Figure 4.7.4a .....	120
Table 4.8.1a .....	123
Figure 4.9.1a .....	124
Figure 4.9.2a .....	125
Figure 5.2a .....	127
Figure 5.2b .....	127
Figure 5.2c .....	128
Figure 5.2d .....	129
Table 7.1a .....	133
Table 7.1b .....	134
Table 7.1c.....	134
Table 7.1d .....	135
Table 7.1e .....	136
Table 7.3a .....	138