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The Design Of An Electric Fence Monitoring System

A thesis presented in partial fulfilment of the
requirements for the degree of Master of
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Abstract



This thesis presents the design of an Electric Fence Monitoring System (EFMS) which detects and annunciates fence malfunctions indicating operational ineffectiveness.

The EFMS consists of a master unit and up to sixteen slave units. Each slave unit monitors a single remote point on the fence. Slave units gain their power from the electric fence pulse itself. They use a unique transmission algorithm to transmit the peak electric fence voltage, to the master unit. The electric fence wire is used to convey this transmission.

The master unit uses a non-linear switched capacitor filter with variable gain control, to detect the slave unit transmissions. This unit displays the peak voltage at each monitored point and allows the setting of alarm trigger points.

This thesis includes modelling of the electric fence energiser and typical electric fence line, and the detailed design of the two units that makeup the EFMS.

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Contents



Abstract	ii
Acknowledgments.....	iii
Contents	iv
List of Figures	ix
List of Tables.....	xii
Units and Symbols.....	xiii
1 Introduction	1
2 The Electric Fence.....	4
2.1 Electric Fence Operation.....	5
2.1.1 The Electric Fence System.....	5
2.1.2 Legal Energiser Requirements.....	5
2.1.3 Energiser Operation.....	6
2.1.4 Typical Energiser Output.....	7
2.1.5 Fence Characteristics.....	8
2.2 Problems With Electric Fence Operation.....	10
2.3 Current Fence Monitoring Solutions.....	11
2.3.1 Electric Fence Voltmeter.....	11
2.3.2 Agricultural Monitor.....	12
2.3.3 Fixed Monitoring Devices.....	12
2.3.4 Wireless Alarm Monitoring Systems.....	13
2.3.5 McCutchan Monitoring System.....	13
2.3.6 Problems With Current Monitoring Solutions.....	14
2.4 Parameters For Ideal Monitoring System.....	15
3 The EFMS System	16
3.1 System Outline.....	17
3.2 Modelling.....	20
3.2.1 The Need For Modelling.....	20
3.2.2 The Electric Fence Model.....	20
3.2.2.1 Fence Model Circuit.....	21
3.2.2.2 Fence Model Results.....	22
3.2.3 The Energiser Model.....	22
3.2.3.1 Energiser Model Circuit.....	22
3.2.3.2 Energiser Model Output.....	26
3.2.3.3 Uses Of The Energiser Model.....	27
3.3 Case Study Analysis.....	29
3.3.1 Nominal Π Circuit Approximation.....	29

3.3.2 Energiser To Slave Line Simulation	29
3.3.3 Slave Unit Power Consumption	31
3.3.4 Slave To Master Line Simulation	32
3.3.5 Case Study Conclusions.....	34
3.4 Methods of Communication.....	35
3.4.1 Traditional Approach.....	35
3.4.2 Pulse Density Method.....	36
3.4.3 Improved Pulse Density.....	39
4 The Slave Unit.....	42
4.1 The Power Supply	44
4.1.1 Power Supply Requirements	44
4.1.2 Circuit alternatives.....	44
4.1.3 Chosen Power Supply Method.....	45
4.1.3.1 Power Supply Circuit Refinement.....	47
4.1.4 Transformer Specifications Summary.....	59
4.2 Measurement System.....	61
4.2.1 Measurement And Transmission Control Alternatives	61
4.2.1.1 Dedicated A/D Based System.....	61
4.2.1.2 Analogue Measurement And Transmission Control	62
4.2.1.3 Multiple Capacitor Peak Detection And A/D Conversion	66
4.2.1.4 Single Capacitor Peak Detection And A/D Conversion.....	68
4.2.2 Measurement Method Chosen.....	70
4.3 Transmission Circuit	71
4.3.1 Transmission Alternatives	71
4.3.1.1 Pulse.....	71
4.3.1.2 Frequency Burst.....	71
4.3.1.2.1 Square Wave.....	72
4.3.1.2.2 Sine Wave.....	72
4.3.2 Modelling Of The Transmission Circuit.....	73
4.3.3 Transmission Circuit Components.....	77
4.3.4 Transmission Driver Circuit	78
4.4 Microprocessor.....	81
4.4.1 Power Up Circuit.....	81
4.4.1.1 Reference Diode With Positive Feedback For Turn On.....	81
4.4.1.2 TL431 With Hysteresis	83
4.4.1.3 PUT.....	84
4.4.1.4 Power Supply Monitor IC.....	85
4.4.1.5 Power Up Method Chosen.....	87
4.4.2 Microprocessor Oscillator.....	87
4.4.2.1 Oscillator Speed.....	87
4.4.2.2 Oscillator Circuit.....	88
4.4.3 Frequency Synthesis	90
4.4.4 Software.....	91
4.4.4.1 Overall Program Flow.....	92
4.4.4.2 Energiser Detection	93
4.4.4.3 Pulse Amplitude Measurement	94
4.4.4.4 Transmission Calculation	94
4.4.4.5 Slave Unit Identification.....	94

4.4.4.6 Timeslot Discrimination	95
4.4.4.7 Transmission.....	95
4.5 PCB Layout.....	96
4.6 Packaging.....	97
5 The Master Unit.....	99
5.1 Attenuation Of The Slave Transmissions.....	102
5.1.1 Impedance Measurements.....	102
5.1.2 Impedance Adjustment Options	104
5.1.3 Slave Transmission Amplitude Measurement	105
5.1.4 Final Design Criteria.....	107
5.2 Signal Filtering	109
5.2.1 Filter Requirements.....	110
5.2.2 Traditional Filter Design	112
5.2.3 Traditional Design Problems.....	112
5.2.4 Filter Solution Options.....	114
5.2.4.1 Use Of Multiple Filters.....	114
5.2.4.2 Adjust Filter Clock Speed	114
5.2.4.3 Change Filter Parameters	116
5.2.5 Noise Pickup	116
5.2.5.1 Reducing Clock Amplitudes.....	116
5.2.5.2 Adjusting Filter Gains	117
5.2.6 Final Circuit.....	118
5.2.7 Post Filter Signal Conditioning	119
5.2.7.1 Signal Rectifier	119
5.2.7.2 Integrator.....	120
5.2.7.3 Peak Detector	122
5.2.7.4 A/D Converter.....	123
5.2.8 Filter Noise.....	124
5.3 Filter AGC.....	126
5.3.1 AGC Requirements.....	126
5.3.2 AGC Circuit	126
5.3.3 AGC Circuit Protection	130
5.4 Master Unit User Interface.....	131
5.4.1 The Master Unit Display.....	131
5.4.1.1 Information To Display.....	131
5.4.1.2 Grid Style Display.....	131
5.4.1.3 Row Display	132
5.4.1.4 Rolling Screen	132
5.4.2 The Master Unit Keypad.....	133
5.4.2.1 Functions To Perform.....	133
5.4.2.2 Keypad Layout	133
5.5 Microprocessors.....	135
5.5.1 Filter Microprocessor	135
5.5.1.1 Energiser Pulse Detection	135
5.5.1.2 Opto-Transmitter.....	136
5.5.1.3 Reset/Watchdog Timer	137
5.5.1.4 Software.....	137
5.5.2 User Interface Microprocessor.....	140

5.5.2.1	Opto-Receiver	141
5.5.2.2	Alarms	141
5.5.2.3	Reset/Watchdog Timer	142
5.5.2.4	EEPROM	142
5.5.2.5	Software	143
5.6	Power Supply	149
5.6.1	Power Supply Requirements	149
5.6.2	Power Supply Design	150
5.7	PCB Layout.....	153
5.7.1	Fence PCB	153
5.7.2	Filter Microprocessor System PCB	153
5.7.3	User Interface Microprocessor System PCB	154
5.8	Packaging	156
6	EFMS Testing	158
6.1	Test Farm Layout	159
6.2	EFMS Tests.....	160
6.2.1	Test 1: Slave Power-Up.....	160
6.2.2	Test 2: Slave Accuracy	160
6.2.3	Test 3: Slave Accuracy Variation	160
6.2.4	Test 4: System Performance	160
6.2.5	Test 5: System Performance With Induced Noise.....	161
6.3	Test Results.....	162
6.3.1	Test 1 Results.....	162
6.3.2	Test 2 Results.....	162
6.3.3	Test 3 Results.....	162
6.3.4	Test 4 Results.....	163
6.3.5	Test 5 Results.....	163
6.4	Test Conclusions	165
7	Conclusions	166
7.1	The Contribution Of This Work	166
7.1.1	Energiser And Fence Modelling	166
7.1.1.1	Fence Model.....	166
7.1.1.2	Energiser Model	166
7.1.2	The EFMS System.....	167
7.1.2.1	Transmission Algorithm	167
7.1.2.2	The Slave Unit	167
7.1.2.3	The Master Unit.....	168
7.2	Extensions To The Work.....	169
7.2.1	EFMS Cost Reduction.....	169
7.2.2	EFMS Extension	169
7.2.3	Model Improvements.....	169
Appendix 1:	The Fence Model	170
Appendix 2:	The Energiser Model.....	172
Appendix 3:	Measurement Circuit Model.....	175

Appendix 4: Transmission Circuit Model	176
Appendix 5: Slave Unit Software.....	178
Appendix 6: Slave Unit Schematics	184
Appendix 7: Master Unit Software.....	188
Appendix 8: Master Unit Schematics	221
References	227

List Of Figures



Figure

1.1	EFMS System Configuration	2
2.1	Electric Fence Operation	5
2.2	Typical Energiser Circuit Diagram.....	6
2.3	Typical Low Power Energiser Output Form For Various Loads.....	7
2.4	Typical RFI Suppression Energiser Output Form, For Various Loads.....	8
2.5	Equivalent Π Circuit.....	8
2.6	Example Electric Fence Layout	10
2.7	Speedrite Electric Fence Voltmeter.....	11
2.8	Agricultural Fence Monitor	12
2.9	Wireless Monitoring System.....	13
2.10	McCutchan Monitoring System	14
3.1	EFMS Configuration	17
3.2	Time Division Between Pulses For EFMS	18
3.3	Electric Fence Model Circuit	21
3.4	Energiser And Electric Fence Model.....	23
3.5	SM5800 Speedrite Energiser Output	26
3.6	Energiser Model Output	27
3.7	Energiser Model Output, No Fault Conditions At Device	30
3.8	Energiser Model Output Over 10km Fence With Fault.....	31
3.9	Pulse Reply	32
3.10	Frequency Burst Reply	33
3.11	Non-Linear Quantisation	36
3.12	Pulse Density Method Transmission	37
3.13	Pulse Density Method.....	38
3.14	Max PD Error vs Number Of Pulses Tested.....	39
3.15	Improved PD Errors.....	41
4.2	Flyback Transformer	44
4.3	Slave Unit Power Supply.....	45
4.4	Power Supply Circuit Testing Under Load	47
4.5	Power Supply Testing With No Load	48
4.6	Capacitive And Inductive Transformer Current In (Loaded)	50
4.7	Transformer Current Out.....	51
4.8	Matlab Energy Calculation Example.....	52
4.9	Transformer Current In (Loaded), Standard vs Grain Orientated.....	54
4.10	BH Curve Measurement Experiment Setup.....	54
4.11	BH Curves Standard and Grain Laminations.....	57
4.12	Transformer Residual Flux	57
4.13	Transformer Current In, Open Circuit, Normal And Reverse Biased	58
4.14	Gapping Of Transformer Core.....	58
4.15	Transformer Current In, Open Circuit, Normal And Reverse Biased	59

Figure

4.16	Dedicated A/D Measurement And Transmission Control System.....	62
4.17	Complete Analogue Measurement And Transmission Control.....	62
4.18	Complete Analogue System, V_{C2} Voltage Variation Over Time For Varying Input Voltage	64
4.19	Complete Analogue System Responses vs Decoded Output.....	65
4.20	Multiple Capacitor Peak Detection And A/D Conversion Circuit	66
4.21	Multiple Capacitor Input Voltage vs Measurement Time	67
4.22	Single Capacitor Peak Detection And A/D Conversion	68
4.23	Comparator Protection Circuitry	69
4.24	Conversion Times For Single Capacitor A/D Method	70
4.25	Pulse Slave Unit Transmissions.....	71
4.26	Transformer Switching Response	72
4.27	Transmission Resonant Circuit	73
4.28	Modelled Transmission Circuit	74
4.29	Slave Transmission Simulation	75
4.30	Slave Unit Transmission Simulation With Large Inductor Resistance	76
4.31	Slave Unit Transmission Simulation With Errant Components	77
4.32	Electrolytic Capacitors Replacing Bipolar Capacitors	77
4.33	Emitter Follower Output Driver	78
4.34	Slave Unit Transmission Driver Transistor Configuration.....	79
4.35	Slave Unit Transmission Driver Circuit.....	80
4.36	Microprocessor Power Up Circuit.....	81
4.37	Reference In Series With Control Switch.....	82
4.38	Reference In Pass Transistor Base Current Path.....	82
4.39	Parallel Reference Diode With Hysteresis	83
4.40	TL431 With Hysteresis.....	84
4.41	PUT Power Up Circuit.....	85
4.42	Power Supply Monitor IC Power Up Circuit	86
4.43	Thevenin Equivalent Resistor Circuit	86
4.44	Microprocessor Power Consumption In Idle Mode.....	88
4.45	Standard Oscillator Circuit	88
4.46	Microprocessor Idle Power Consumption.....	89
4.47	Microprocessor Oscillator Circuit (Internal Oscillator).....	89
4.48	Microprocessor Oscillator Circuit (External Oscillator).....	90
4.49	Typical Fence Line Equivalent Π Circuit	90
4.50	Slave Unit Software Flow Diagram	93
4.51	Energiser Pulse Detector Circuit.....	94
4.52	Slave Unit ID Selection	95
4.53	Slave Unit PCB	96
4.54	Slave Unit Chassis Packaging	97
4.55	Slave Unit Case Packaging.....	98
5.1	Master Unit Block Diagram.....	99
5.2	The Master Unit	101
5.3	Slave Unit Transmission Equivalent Circuit.	102
5.4	Energiser Impedance Measurement.	103
5.5	Master Unit Impedance Switch Configuration.....	104
5.6	Series Fence Impedance Switch.....	104

Figure

5.7	Slave Unit Transmission Amplitude Measurement.	105
5.8	Slave Transmission Amplitudes	106
5.9	Impedance Design Criteria.	107
5.10	Slave Unit Transmission Amplitude Measurement.	110
5.11	Master Filter Requirements.	111
5.12	Chebyshev Filter.	111
5.13	Theoretical Filter Output.	112
5.14	Timeslot Filter Response.	113
5.15	Multiple Filter Switching.	114
5.16	Switched Clock Filter Output.	115
5.17	Reducing Filter Q.	116
5.18	Reducing Filter Clock Amplitude.	117
5.19	Filter Noise Pickup.	117
5.20	Filter Stage Schematic.	118
5.21	Signal Rectifier.	120
5.22	Integrator.	121
5.23	Rectifier Output For Noise (a) and Transmission (b).	121
5.24	Integrator Output For Noise (Dashed) and Transmission (Solid).	122
5.25	Peak Detector Output.	123
5.26	Peak Detector.	123
5.27	A/D Sample Rate	124
5.28	Signal Rectifier.	127
5.29	AGC Multiplexer.	129
5.30	Complete AGC Circuit	130
5.31	Grid Style Display.	131
5.32	Row Display.	132
5.33	Rolling Screen.	132
5.34	Keypad Layout.	134
5.35	Energiser Pulse Detector.	136
5.36	Opto-Transmitter.	137
5.37	Filter Microprocessor Reset Circuit	137
5.38	Filter Microprocessor Software.	138
5.39	Filter Output Peaks.	139
5.40	Optical Receiver Circuit.	141
5.41	Buzzer Circuit.	142
5.42	User Interface Microprocessor Reset Circuit	142
5.43	EEPROM Circuit.	143
5.44	User Interface Microprocessor Software	145
5.45	Master Unit Power Supply.	152
5.46	Prototype Fence PCB	153
5.47	Prototype Filter Microprocessor System PCB.	154
5.48	Prototype User Interface Microprocessor System PCB	155
5.49	Master Unit Packaging	156
5.50	Master Unit Assembly	
6.1	Test Farm Layout	159
6.2	Test 4 Slave Unit Positioning.	161
6.3	Induced Noise At A/D Input.	164

List Of Tables



Table

2.1	Legal Energiser Requirements	6
3.1	Operation Parameters For The EFMS.....	19
3.2	Electric Fence Parameters.....	21
3.3	Nominal Π Circuit Approximation.....	29
4.1	Slave Unit Transformer Configurations.....	48
4.2	Energy Balance Standard Laminations	52
4.3	Energy Balance Grain Orientated Laminations	53
4.4	Circuit Switch On Voltages	83
4.5	Transmission Frequency Selection	91
5.1	Energiser Impedance	103
5.2	Slave Unit Transmission Amplitude	106
5.3	AGC Resistances.....	129
5.4	Accuracy Settings.....	146
5.5	Filter Microprocessor System Power Consumption.....	149
5.6	User Interface Microprocessor System Power Consumption	150
6.1	Test 2 Slave Accuracy Results.....	162
6.2	Test 3 Slave Variation Accuracy Results	162
6.3	Test 4 Slave Performance	163
6.4	Test 5 Slave Performance Under Noise.....	163

Units And Symbols



Quantity	Symbol for Quantity	Unit	Symbol for Unit
Admittance	Y	siemens	S
Angular velocity	ω	radians/second	rad/s
Area	A	square metre	m ²
Capacitance	C	Farad	F
Charge	Q	Coulomb	C
Conductance	G	siemens	S
Current	I	Ampere	A
Energy	E	Joule	J
Flux	θ	Weber	Wb
Flux Density	B	Tesla	T
Frequency	f	Hertz	Hz
Impedance	Z	Ohm	Ω
Inductance	L	Henry	H
Instantaneous current	i	Ampere	A
Length	l	metre	m
Magnetic Field Strength	H	Ampere/metre	A/m
Number of turns on winding	N	(dimensionless)	
Period	T	second	s
permeability	μ	henry/metre	H/m
Power	P	Watt	W
Resistance	R	Ohm	Ω
Selectivity	Q	(dimensionless)	
Time	t	second	s
Voltage	V	Volt	V

The following prefixes are used in conjunction with the above units.

Prefix	Symbol	Fraction
pico	p	10 ⁻¹²
nano	n	10 ⁻⁹
micro	μ	10 ⁻⁶
milli	m	10 ⁻³
kilo	k	10 ³
mega	M	10 ⁶

The following symbols are used throughout this thesis:

Quantity	Symbol for Quantity	Unit	Symbol for Unit
Propagation Constant	γ	(dimensionless)	
Transformer gap permeability	μ_{AIR}	Henry/metre	H/m
Transformer core permeability	μ_{CORE}	Henry/metre	H/m
Sample duration	Δt	second	s
Effective area of transformer core	A_l	square metre	m ²
Energiser storage capacitance	C_e	Farad	F
Electric fence capacitance	C_F	Farad	F
Electric fence capacitance	C_f	Farad	F
RFI suppression capacitance	C_S	Farad	F
Energy lost into inter-winding capacitance	E_{cap}	Joule	J
Energy lost in resistance of transformer windings	E_{copper}	Joule	J
Energy lost in resistance of transformer primary winding	$E_{copper.primary}$	Joule	J
Energy lost in resistance of transformer secondary winding	$E_{copper.secondary}$	Joule	J
Energy lost in diodes	E_{diode}	Joule	J
Energy lost in rectifier diodes	$E_{diode.rectifier}$	Joule	J
Energy lost in regulator diode	$E_{diode.regulator}$	Joule	J
Energy delivered into primary of transformer	E_{in}	Joule	J
Energy lost in resistance of inductor	$E_{inductor.wire}$	Joule	J
Energy lost in measurement components	$E_{measure}$	Joule	J
Transmission energy	E_T	Joule	J
Energy loss not attributable to one specific cause	$E_{transformer}$	Joule	J
Filter centre frequency	f_0	Hertz	Hz
Filter clock frequency	f_{CLK}	Hertz	Hz
Power supply form factor	ff	(dimensionless)	
Transformer gap factor	G_F	(dimensionless)	
Filter output high pass gain	H_{OHP}	(dimensionless)	
Filter output low pass gain	H_{OLP}	(dimensionless)	
Filter output notch gain	H_{ON2}	(dimensionless)	
Power supply AC current	I_{AC}	Ampere	A
Power supply DC current	I_{DC}	Ampere	A
Transformer input current	I_{in}	Ampere	A
Transformer output current	I_{out}	Ampere	A
Peak current	I_{peak}	Ohms	Ω
Diode saturation current	I_S	Ampere	A
Chebyshev filter gain constant	K	(dimensionless)	

Transformer core magnetic path length	l_{CORE}	metre	m
Transformer gap length	l_{GAP}	metre	m
Transformer magnetising inductance	L_{M}	Henry	H
Slave unit power supply inductance	$L_{\text{power.supply}}$	Henry	H
RFI suppression inductance	L_{S}	Henry	H
Leakage Inductance of transformer primary	L_{T1}	Henry	H
Leakage Inductance of transformer secondary	L_{T2}	Henry	H
Electric fence inductance	L_{W}	Henry	H
Number of energiser pulses counted	m	(dimensionless)	
Number of data samples	N	(dimensionless)	
Number of energiser pulses	n	(dimensionless)	
Number of slave units	n	(dimensionless)	
Number of capacitive current data samples	N_{C}	(dimensionless)	
Number of falling output current data samples	N_{F}	(dimensionless)	
Number of rising output current data samples	N_{R}	(dimensionless)	
Transformer turns ratio	N_{R}	(dimensionless)	
Number of positive responses	p	(dimensionless)	
AGC resistance	R_{AGC}	Ohms	Ω
Ground Resistance	R_{G}	Ohms	Ω
Load Resistance	R_{L}	Ohms	Ω
Transformer core loss resistance	R_{M}	Ohms	Ω
Resistance of measurement components	R_{measure}	Ohms	Ω
Filter equivalent feedback resistance	R_{N}	Ohms	Ω
Transformer primary resistance	R_{T1}	Ohms	Ω
Transformer secondary resistance	R_{T2}	Ohms	Ω
Thevenin equivalent resistance	R_{TH}	Ohms	Ω
Electric fence wire resistance	R_{W}	Ohms	Ω
Resistance of transformer winding	R_{wire}	Ohms	Ω
Time taken for capacitor to charge	t_{c}	second	s
Transformer utilisation constant	TU	(dimensionless)	
Power supply AC voltage	V_{AC}	Volt	V
Voltage drop across transistor base emitter junction	V_{be}	Volt	V
Measurement capacitor voltage	V_{c}	Volt	V
Power Supply Voltage	V_{CC}	Volt	V

Power supply DC voltage	V_{DC}	Volt	V
Power supply rectifier diode voltage drop	V_{DIODE}	Volt	V
Power supply regulator voltage drop	V_{DROP}	Volt	V
Peak fence voltage	V_{fence}	Volt	V
Voltage drop across FET drain source	V_{FET}	Volt	V
Transformer input voltage	V_{in}	Volt	V
Maximum output voltage	V_{max}	Volt	V
Transformer output voltage	V_{out}	Volt	V
Peak transmission voltage	V_P	Volt	V
Voltage drop across pullup resistor	V_{pullup}	Volt	V
Measurement resistor voltage	V_r	Volt	V
Power supply ripple voltage	V_{Ripple}	Volt	V
Diode threshold voltage	V_T	Volt	V
Transformer voltage	V_T	Volt	V
Thevenin equivalent voltage	V_{TH}	Volt	V
Voltage across energiser	V_{Ze}	Volt	V
Shunt admittance per unit length	y	Siemens	S
Equivalent Admittance	Y'	Siemens	S
Series Impedance per unit length	z	Ohms	Ω
Equivalent Impedance	Z'	Ohms	Ω
Characteristic Impedance	Z_c	Ohms	Ω
Energiser impedance	Z_e	Ohms	Ω
Impedance of slave unit	Z_{slave}	Ohms	Ω