RADIO EVALUATION KIT RFEVAL1
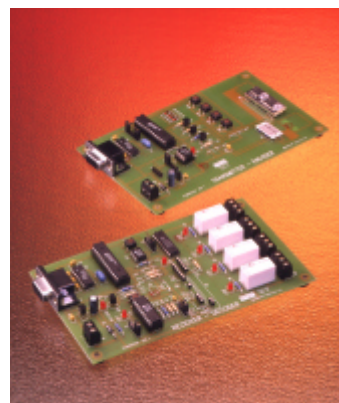
R.F. Solutions LTD.

FEATURES

- HARDWARE EVALUATION PLATFORM
- RANGE TESTING
- TARGET ENVIRONMENT TESTING
- ANTENNA EVALUATIONS
- AM / FM COMPARISON & SELECTION
- ENCODING / DECODING TESTING
- REMOTE SWITCHING
- DATA COMMS

DESCRIPTION

The RFEVAL1 is a hardware development platform designed to assist the engineer with a 'Low Power Radio' Application.

This evaluation kit provides easy to build telemetry and data communications applications which may utilise various hardware and software encoders and decoders and also with a variety of radio modules.

This enables the engineer to select the optimum radio module and antenna type for a specific target application.

Primarily as a hardware development platform, the development boards are a transmitter PCB and a receiver PCB, both of which can accommodate either AM or FM modules. An RS232 serial port is included on each board to allow the designer to connect the boards to PC's and thus create more advanced, data communication systems

When completed the system may be used as a complete radio system.

Three projects are studied in detail;

1. **Simple Radio Switched Relay** using Keeloq HCS360 encoder & HCS512 Decoder. (A hardware solution)
2. **Remote telemetry switching** using Keeloq HCS360 encoder & PIC16C73 Decoder (a software solution)
3. **Radio Data Communications**; Transmitting a data byte between two PC's

The boards are supplied part populated with a pre-tuned PCB antenna ready for use. The user simply populates the PCB's to the specific schematic diagram as per the project required.

CONTENTS LIST

Encoder Board	Part No: PCB00229ASSY
Decoder Board	Part No: PCB00228
Floppy Disk	Part No: RFEVAL1-SOFTWARE
Encoder I/C PWM	Part No: FW000038 (marked '38')
Encoder I/C Manchester	Part No: FW000039 (marked '39')

POWER SUPPLY

Both transmitter and Receiver Board may be powered from any DC voltage from 9 – 20V
The Transmitter encoder Board requires up to 15mA when transmitting.
The receiver decoder Board requires up to 20mA.

CONNECTOR SETTINGS

There are several connectors on the boards which are described below;

TRANSMITTER

J1: Power connector, connect DC power supply to this connector.

J5: HCS360 switch input connector, connect external switches to this connector.
Note that the +5V feed on J5-1 is common supply to all the switches.

J8: HCS360 programming connector. Only use this connector if you require to custom program the HCS360 with specific information e.g. custom manufacturers Key etc, otherwise this can be ignored.

Connector	Connector Type	Function
J1-1	2 way screw terminal 5.08mm pitch	+12V in Power Supply
J1-2		0V in Power Supply
J5-1	5 way link header 2.54mm pitch	+5V feed for switch inputs
J5-2		HCS360 switch input 0
J5-3		HCS360 switch input 1
J5-4		HCS360 switch input 2
J5-5		HCS360 switch input 3
J8-1	4 way link header 2.54mm pitch	HCS360 pin 5 - GND programming connection
J8-2		HCS360 pin 8 - VCC programming connection
J8-3		HCS360 pin 4 - CLK programming connection
J8-4		HCS360 pin 6 - DATA programming connection

RECEIVER

J3: This is the input to the relay driver (ULN2803A) connector. If pins J3-1 to J3-4 are connected to pins J5-1 to J5-4 the HCS512 decoder will switch the onboard relays.

J5: This is the output from the HCS512 decoder I/C. these jumper links may be connected to J3 to drive the on board relays, or to external circuitry.

J6 – J9: These are screw terminals to the contact side of the relay. These provide 'volt free' switches from Relays 1to 4. Three connections are provided; a common, Normally closed and Normally open.

Connector	Connector Type	Function
J1-1	2 way screw terminal 5.08mm pitch	+12V in
J1-2		0V in
J3-1	5 way link header 2.54mm pitch	Relay driver input 1
J3-2		Relay driver input 2
J3-3		Relay driver input 3
J3-4		Relay driver input 4
J3-5		+5V
J5-1	5 way link header 2.54mm pitch	HSC512 output 0 (Active High)
J5-2		HSC512 output 1 (Active High)
J5-3		HSC512 output 2 (Active High)
J5-4		HSC512 output 3 (Active High)
J5-5		GND
J6-1	3 way screw terminal 5.08mm pitch	Relay 1 normally closed
J6-2		Relay 1 common
J6-3		Relay 1 normally open
J7-1	3 way screw terminal 5.08mm pitch	Relay 2 normally closed
J7-2		Relay 2 common
J7-3		Relay 2 normally open
J8-1	3 way screw terminal 5.08mm pitch	Relay 3 normally closed
J8-2		Relay 3 common
J8-3		Relay 3 normally open
J9-1	3 way screw terminal 5.08mm pitch	Relay 4 normally closed
J9-2		Relay 4 common
J9-3		Relay 4 normally open

NOTES ON ANTENNA

The transmitter antenna has been incorporated as a PCB 'tuned loop'. Designed to resonate at 433.92MHz the loop has been designed to be the most efficient method for transmitting the signal from the smallest possible size.
Note the SMT capacitors mounted on the PCB tune the loop to 433.92MHz.
If copying these loop antenna to other applications, The required capacitor values are;

For the AM module at 433MHz
$\qquad$ C11 (Feed Cap) = 1pF
$\qquad$ C12 (Cap in Loop) = 1.8pF

For the FM module at 433MHz
$\qquad$ C1 (Feed Cap) = 10pF
$\qquad$ C2 (Cap in Loop) = 1.5pF
$\qquad$ C3 (Cap in Loop) = 1pF

The following type approved antennas may also be used with the transmitter and the receiver. Note that if an alternative antenna is to be fitted then remember to remove the connection to the PCB track antenna by removing the feed capacitor!

ANTENNA 1 – HELICAL COIL (PART NO PU-4BA-433, PU-BNC-433)

Wire coil, connected directly to RF in/out, open circuit at the other end. This antenna has a high Q Factor, for trimming, the length may be adjusted. This is a popular antenna as it consumes little space. The helical de-tunes badly with proximity to other conductive objects.
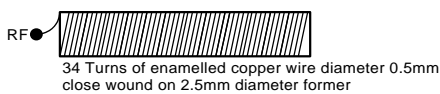
ANTENNA 2 –TUNED LOOP (incorporated on PCB)

A PCB track tuned by the capacitor to ground at the 'HOT' end. Fed from ANT pin at a point 20% from the ground end. Loops have a high immunity to proximity de-tuning. e.g. a human hand used to operate the transmitter coming into relative close proximity to the loop.
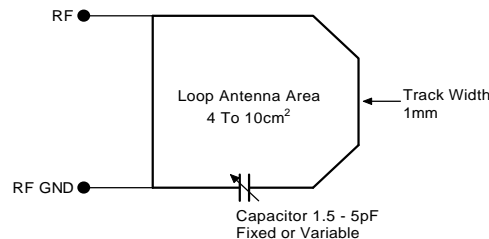
Antenna 3 – Whip (PART NO FLEXI-4BA-433, FLEXI-BNC-433)

Can be either PCB track, wire rod or a combination of the two. One end connected to ANT pin, the other open. Optimum total length is 17.3cm (¼ wave @ 433MHz). The optimum position is to locate the antenna so that it protrudes directly upwards. Keep the open circuit (hot) end well away from metal components to prevent serious de-tuning. Whips are ground plane sensitive and will benefit from internal ¼ wave earthed radial(s) if the product is small and plastic cased.
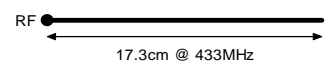
Helical Coil Antenna

RF●
34 Turns of enamelled copper wire diameter 0.5mm
close wound on 2.5mm diameter former

Loop Antenna

RF●
Loop Antenna Area 4 To 10cm^2
Track Width 1mm
RF GND●
Capacitor 1.5 - 5pF
Fixed or Variable

Whip Antenna

RF●
17.3cm @ 433MHz

Figure 1: Antenna Configurations

Advantages / Disadvantages of Each Antenna			
Feature	**Helical**	**Loop**	**Whip**
Performance	☺☺	☺	☺☺☺
Ease of design	☺☺	☺	☺☺☺
Size	☺☺☺	☺☺	☺
Immunity to hand de-tuning and or components in close proximity	☺☺	☺☺☺	☺

Note: The range achieved from the system is dependent on the choice and position of the antenna. The space around the antenna is as important as the antenna itself. Try to keep the antenna away from other metal in the system such as transformers, batteries and PCB tracks, especially ground planes. In particular, the 'HOT' end of the antenna should be kept as far away as possible from these.

PROJECT #1;
REMOTE SWITCHED RELAY USING KEELOQ HCS360 ENCODER & HCS512 DECODER. (A HARDWARE SOLUTION)

Encoder Schematic : Fig 66
Decoder Schematic : Fig 68

This project demonstrates the operation of the Microchip KeeLoq hardware encoder and decoder devices and allows the remote operation of a relay over either an AM or an FM radio link. The data which is transmitted over the radio link is PWM encoded and details of the precise format are given in the HCS360 data sheet (available from Microchip Technology). The hardware for the project is built on the transmitter and receiver evaluation boards and the parts lists are given in appendix B.

The transmitter unit consists of a simple KeeLoq circuit using the HCS360 (marked '38') and the selected AM or FM radio module. The PCB aerial track can be used or alternately a helical stub or 1/4 wave whip aerial can be connected using a short length of 50Ω co-axial cable. The transmitter functions are all handled by the HCS360 which outputs a PWM coded data stream and so designer should ensure that the HCS360 marked '38' is used. The PWM output is directly compatible with the HCS512 decoder.

The receiver unit consists of an AM or an FM radio module, (selected to match the transmitter module) and the HCS512 KeeLoq device and its associated components. In addition it will be necessary to connect an external aerial and this can take the form of either a helical stub or 1/4 wave whip connected using a short length of co-axial cable.

Operation of the system is extremely simple: when the transmitter push (SW1-4) button is operated, the radio module is powered up and while the button is held depressed a series of data frames is transmitted. The receiver radio module is always powered up and it passes the received data to the HCS512 which decodes the data and actuates the relay (RL1-4) when valid frames are being received.

TEACHING A ENCODER TO A DECODER
1. Press the programming switch on the Rx decoder once
2. The learn LED will illuminate
3. Press one of the switches on the Tx encoder once, learn LED on the Rx decoder will extinguish
4. Press one of the switches on the Tx encoder again, learn LED will flash
5. When the learn LED has stopped flashing this Tx encoder will now operate the system

ERASING EXISTING TX ENCODER
1. To completely erase the Tx encoders, press programming switch on the Rx decoder for 10 seconds.
2. The learn LED will turn off after the 10 seconds to indicate the Tx encoder(s) have been erased

PROJECT #2;
REMOTE TELEMETRY SWITCHING USING KEELOQ HCS360 ENCODER & PIC16C73 DECODER (A SOFTWARE SOLUTION)

Encoder Schematic : Fig 66
Decoder Schematic : Fig 70

This project provides a remote telemetry function as in project #1. However the decoding is performed within a standard PIC microcontroller instead of within a dedicated Keeloq decoder I/C. For this reason the Keeloq encoder part HCS360 marked '39' should be used.

For applications where a simple remote control feature is required as a low cost 'bolt on feature' this project is most applicable. The decoding of the Keeloq data can be performed as one small task of the main microcontroller that exists within the application. This reduces the hardware cost to a minimum, as a receiver is the only additional hardware required.

The transmitter encoder is the same as Project #1. It is assumed that for production a commercially available keyfob/transmitter encoder will be used. This will already have all the relevant EMC compliance for licence free use.

For this project , the chosen microcontroller is the PIC16C73A, however many other microcontrollers may be used. If another PIC is to be used then the assembler code may well be ported directly across.

The data which is transmitted over the radio link is Manchester encoded and details of the precise format are given in the HCS360 data sheet (available from Microchip Technology). The receiver captures the information and outputs the CMOS/TTL data to the PIC16C73A.
The PIC16C73A decodes the data and outputs the relevant signal to the relays so that when the user presses switch '1 to 4' the relays' 1 to 4 will operate.

The transmitter functions are all handled by the HCS360 which outputs a MANCHESTER coded data stream and so designer should ensure that the HCS360 marked '39' is used. The MANCHESTER output provides a better signal type for the radio link thus achieving a greater range than in PWM systems.

When completed the reader may note that the telemetry link may be further secured by using a unique 'manufacturers Key'. What this means is that the transmitted signal is customised with a unique encrypted number. This number is totally secure and cannot be read or interpreted by any third party. Only a decoder with the same manufacturers key may decrypt this number. Further information is detailed in Appendix A. The result is a remote control system where only the transmitter encoder with this special manufacturers key may be learnt by the receiver decoder (with its own matching manufacturers key).

The part list is shown in Appendix B.

The software included on the floppy disk provides the following software;

P403.asm	This is the main source code routine
P403man.asm	This is the source subroutine 'MAN'
P403PWM.asm	This is the source subroutine 'PWM'
PIC16c73A.inc	This is an Include file used by MPLAB
P403.lst	This is the complete Listing File
P403.hex	This is the object code which may be directly programmed into the PIC

PROJECT #3;
TRANSMITTING A DATA BYTE BETWEEN TWO PC'S

Encoder Schematic : Fig 72
Decoder Schematic : Fig 74

This project looks briefly at the problems of passing serial data over a low power radio link and takes the designer down the first steps in designing a simple 'Radio Packet Controller' (RPC) which could be extended to include error detection and other more advanced features.

It is not possible to simply feed asynchronous data into a radio module and expect the data to emerge 'unscathed' from the receiver module. For this reason a 'Radio Packet Controller' (RPC) is available specifically designed to enable asynchronous data transmission

The basic problem with transmitting serial asynchronous data between say a couple of PC's is that the data content is not likely to be 'balanced' (100% ac content). This would cause the radio module receiver to malfunction because of the receive data slice circuitry becoming biased by a cumulative string of '1' or '0' bits which appear in the received data. It may in some instances be possible to encode the data in the transmitting PC such that this problem is minimised, but in general this is not a valid option. Most applications will require an interface between the RS232 port on the PC and the radio transmitter module, which codes the data to give optimum performance from the radio link irrespective of the content of the data which is being transmitted. This function is normally combined with the creation of a data packet structure where individual characters are not transmitted, but instead a number is sent at a point in time in a composite frame. This also provides receiver biasing and error detection.

The principle of the RPC which is described in this project is simple, the RS232 serial port on the transmitter is used to receive characters from a PC. When eight characters have been received, they are formed into a packet and transmitted as a frame. The frame has a header, and a sync byte, and the data characters are coded in Manchester format. This is similar to the format utilised in the Microchip HCS360 encoder.

The receiving software decodes the frame and outputs the characters on an RS232 port. The system has been designed to be a demonstration of the principles of an RPC and requires that the user enter characters in blocks of 8 with a pause between each block. This is clearly a limitation on the user, which in practice might not be acceptable. However by using the software for this project as a starting point, the software engineer should be able to overcome this by implementing interrupt driven communications and more complex buffering at both ends of the link.

The transmitter and receiver boards both use the PIC16C73A processor and these devices communicate with the PC's using the PIC on board UART's and over RS232 data links which are supported by the on board level shifter circuitry. The system will function with either AM or FM radio modules and is an excellent way of carrying out module selection and also as a means of testing out different aerial systems.

The software for the transmitter runs in a PIC16C73A and consists of two main blocks which carry out the following functions:

1. Transmitter reception of 8 data bytes and their transfer into a buffer from the host PC using the PIC16C73's on board UART.
2. Transmission of a frame of RF data consisting of a preamble, a synchronous element, the actual data block itself in Manchester format and a guard period.

The software for the receiver runs in a PIC 16C73 and again consists of two main blocks which carry out the following functions:

1. Reception of the frame and transfer of the data into a buffer.
2. Transmission of the 8 data bytes to the PC using the on board UART.

The software included on the floppy disk provides the following software;

Transmitter Encoder software

    P404.asm   This is the main source code routine
    P404man.asm   This is the source subroutine 'MAN'
    P404sub.asm   This is the source subroutine 'PWM'

    PIC16c73A.inc This is an Include file used by MPLAB

    P404.lst   This is the complete Listing File

    P404.hex   This is the object code which may be directly programmed into the PIC

Receiver Decoder software

    P405.asm   This is the main source code routine
    P405sub.asm   This is the source subroutine 'PWM'

    PIC16c73A.inc This is an Include file used by MPLAB

    P405.lst   This is the complete Listing File

    P405.hex   This is the object code which may be directly programmed into the PIC

TECHNICAL SPECIFICATIONS

Storage Temperature; -10 to +70° Celsius.
Operating Temperature; 0 to +55° Celsius.

Dimensions:
Enclosure : 190 x 120 x 60 mm
PCB: 174 x 106mm

TRANSMITTER TECHNICAL SPECIFICATION

ELECTRICAL CHARACTERISTICS	MIN	TYPICAL	MAX	DIMENSION
Supply Voltage	11.0	16.0	30.0	V
Supply Current (not including transmitter Module):				
Quiescent			10	mA
Whilst transmitting			2	mA

AM TRANSMITTER MODULE AM-RT4-433, AM-RT5-433 (M1, M2)

ELECTRICAL CHARACTERISTICS	MIN	TYPICAL	MAX	DIMENSION
Working Frequency		433.92		MHz
RF Output Power into 50Ω (Vcc=5V)		0		-dBm
Harmonic Spurious Emissions		-30		-dBc
Time from Power on to data transmission		10		mSec
Operating Temperature Range	-25		+80	^{o}C

FM TRANSMITTER MODULE FM-TX2-433, (M3)

ELECTRICAL CHARACTERISTICS	MIN	TYPICAL	MAX	DIMENSION
supply current	7	10	14	mA
RF power	+6	+9	+12	dBm
2nd harmonic		-65	-54	dBc
Modulation bandwidth @ -3dB	DC	-	20	kHz
overall frequency accuracy	-70	-	+70	kHz
power up time to full RF			100	μs
Operating Temperature Range	-10		+55	^{o}C

RECEIVER TECHNICAL SPECIFICATION

ELECTRICAL CHARACTERISTICS	MIN	TYPICAL	MAX	DIMENSION
Supply Voltage	11.0	16.0	30.0	V
Supply Current (not including receiver module):				
Quiescent		5		mA
All Relays operating		250		mA
Relay Rating RLY1-4			2	A @12Vdc
			1	A @50Vdc

FM RECEIVER MODULE FM-RX2-433 (M1)

ELECTRICAL CHARACTERISTICS	MIN	TYPICAL	MAX	DIMENSION
supply current	11	13	17	mA
RF sensitivity for 10dB (S+N)/N		-113	-107	dBm
initial frequency accuracy	-30	0	+30	kHz
Audio baseband bandwidth @ -3dB	0.006	-	7	kHz
power up to stable data, T_{PU-DAT}		20	-	ms
time between data transitions	15	-	0.07	ms
mark:space ratio	20	50	80	%
Operating Temperature Range	-10		+55	^{o}C

AM RECEIVER MODULE AM-HRR3-433 (M2)

ELECTRICAL CHARACTERISTICS	MIN	TYPICAL	MAX	DIMENSION
Supply Current		2.5	3	mA
R.F Sensitivity 100% AM (AM-HRR3-XXX)	-100	-105		dBm
Time from Power HRR3 on to Valid Output Signal		1.2		Secs
-3dB Bandwidth		+/- 2	+/- 3	MHz
Data Rate	50		2000	Hz
Operating Temperature Range	-25		+85	^{o}C

AM RECEIVER MODULE AM-RRS2-433 (M3)

ELECTRICAL CHARACTERISTICS	MIN	TYPICAL	MAX	DIMENSION
Supply Current		5	6	mA
R.F Sensitivity (100% AM)		-106		dBm
3dB Bandwidth		+/-400		KHz
Max Data Rate			3	KHz
Turn on Time			20	mSecs
Operating Temperature Range	-25		+80	^{o}C

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Appendix A: An Introduction to KEELOQ

The keeloq system is a patented code hopping technology used primarily in remote control applications. The encryption and decryption devices are manufactured by Microchip Technology Inc. and provide an ideal solution to remote control systems. The Keeloq algorithm is a highly secure digital data protocol that uses a 67-bit transmission code. Each time a switch is pressed on a transmitter encoder the data transmitted is different, even if the same switch is pressed twice. A corresponding receiver decoder will also never respond to the same code twice. By using a large number of possible transmission combinations means it would take over 5,000 Billion years for a person to scan through all the possible combinations.

For a Keeloq encoder and decoder to work with each other they both must have the same Manufactures Key. This is 64-bit number that is programmed into each device. Once both chips have the same Manufactures Key then a encoder can be taught to a decoder. The decoder then stores in memory the Serial Number of the encoder, this is a unique number that is programmed into each encoder. In this system the receiver decoder automatically 'hops' in sync with the transmitter encoder. If a transmitter encoder is pressed more than 50 times out of range of the receiver decoder then the system will be out of sync. If this situation occurs then the user only needs to press the switch twice on the transmitter encoder within the range of the receiver decoder for the system to resynchronise.

The keeloq system also has various built in functions. Auto Shut-off Timer is used if a switch on the encoder inadvertently gets pressed for a long period of time. After 25 seconds the auto shut-off function automatically stops the device from transmitting and so prevents the transmitter from draining the battery. The keeloq encoder also transmits the voltage status of the battery. If the battery voltage becomes low then the Keeloq encoder will transmit this information to the decoder. The decoder can then indicate to the user that the transmitter battery needs replacing.

For more detailed information on Keeloq please refer to the Microchip Technology data sheets.

Appendix B: Project Part Lists and Schematic Diagrams

Project #1: Hardware Encoder Parts List

Reference	Value
C1	10pF 0805 Capacitor
C2	1.5pF 0805 Capacitor
C3, C11	1pF 0805 Capacitor
C5	10µF 16V Electrolytic Capacitor
C6, C10	100nF 2.54mm Pitch Capacitor
C12	1.8pF 0805 Capacitor
C13	220pF 0805 Capacitor
D1	3mm LED
D2,D3, D4, D5	1N4148 Diode
D6	1N4001 Diode
IC3	HCS360/P
IC4	L78L05ACZ
J1	2 way screw terminal 5.08mm pitch
J5	5 way link header
J8	4 way link header
M1	AM-RT4-433
M2	AM-RT5-433
M3	FM-TX2-433
Q1	BC212B
Q2, Q3	BC546B
R1	1K5 ¼ Watt
R2, R3, R4	10K ¼ Watt
SW1, SW2, SW3, SW4	DTS619

Project #1: Hardware Decoder Parts List

Reference	Value
C1	10pF 2.54mm pitch
C5	10µF 16V Electrolytic Capacitor
C6	100nF 2.54mm Pitch Capacitor
D1	1N4001 Diode
IC4	L78L05ACZ
IC5	HCS512
IC6	DS1233
IC7	ULN2803A
J1	2 way screw terminal 5.08mm pitch
J3, J5	5 way link header
J4	4 way link header
J6, J7, J8, J9	3 way screw terminal 5.08mm pitch
LED2, LED3, LED4, LED5, LED6, LED7	3mm LED
M1	FM-RX2-433
M2	AM-HRR3-433
M3	AM-RSS2-433
Q1	BC546B
R1, R7, R9, R12, R13, R14	10K ¼ Watt
R3, R4, R5, R6, R8, R11	1K ¼ Watt
R10	100K ¼ Watt
RL1, RL2, RL3, RL4	BT47W/6 Relay
SW2	DTS619

Project #2: Software Encoder Parts List

As per Project #1: Hardware Encoder Parts List

Project #2: Software Decoder Project Parts List

Reference	Value
C5	10µF 16V Electrolytic Capacitor
C6	100nF 2.54mm Pitch Capacitor
D1	1N4001
IC1	PIC16C73A/P
IC3	93LC76
IC4	L78L05ACZ
IC7	ULN2803A
J1	2 way screw terminal 5.08mm pitch
J3	5 way link header
J6, J7, J8, J9	3 way screw terminal 5.08mm pitch
LED1, LED2, LED3, LED4, LED5	3mm LED
M1	FM-RX2-433
M2	AM-HRR3-433
M3	AM-RSS2-433
R1	10K ¼ Watt
R2	470R ¼ Watt
R3, R4, R5, R6	1K ¼ Watt
RL1, RL2, RL3, RL4	BT47W/6
SW1	DTS619
X1	3 pin resonator - 4.0 MHz

Project #3: Transmitter Data Comms Parts List

Reference	Value
C1	10pF 0805 Capacitor
C2	1.5pF 0805 Capacitor
C3, C11	1pF 0805 Capacitor
C4, C6, C7, C8, C9, C10	100nF 2.54mm Pitch Capacitor
C5	10µF 16V Electrolytic Capacitor
C12	18pF 0805 Capacitor
C13	220pF 0805 Capacitor
D2, D3, D4, D5	1N4148 Diode
D6	1N4001 Diode
IC1	PIC16C73A/P
IC2	MAX232A
IC4	L78L05ACZ
J1	2 way screw terminal 5.08mm pitch
J2	9 way D-type female connector
J4	6 way link header
J5	5 way link header
M1	AM-RT4-433
M2	AM-RT5-433
M3	FM-TX2-433
Q1	BC212B
Q2, Q3	BC546B
R1	1K5 ¼ Watt
R2, R3, R4	10K ¼ Watt
SW1, SW2, SW3, SW4	DTS619
X1	3 pin resonator - 4.0 MHz

Project #3: Receiver Data Comms Parts List

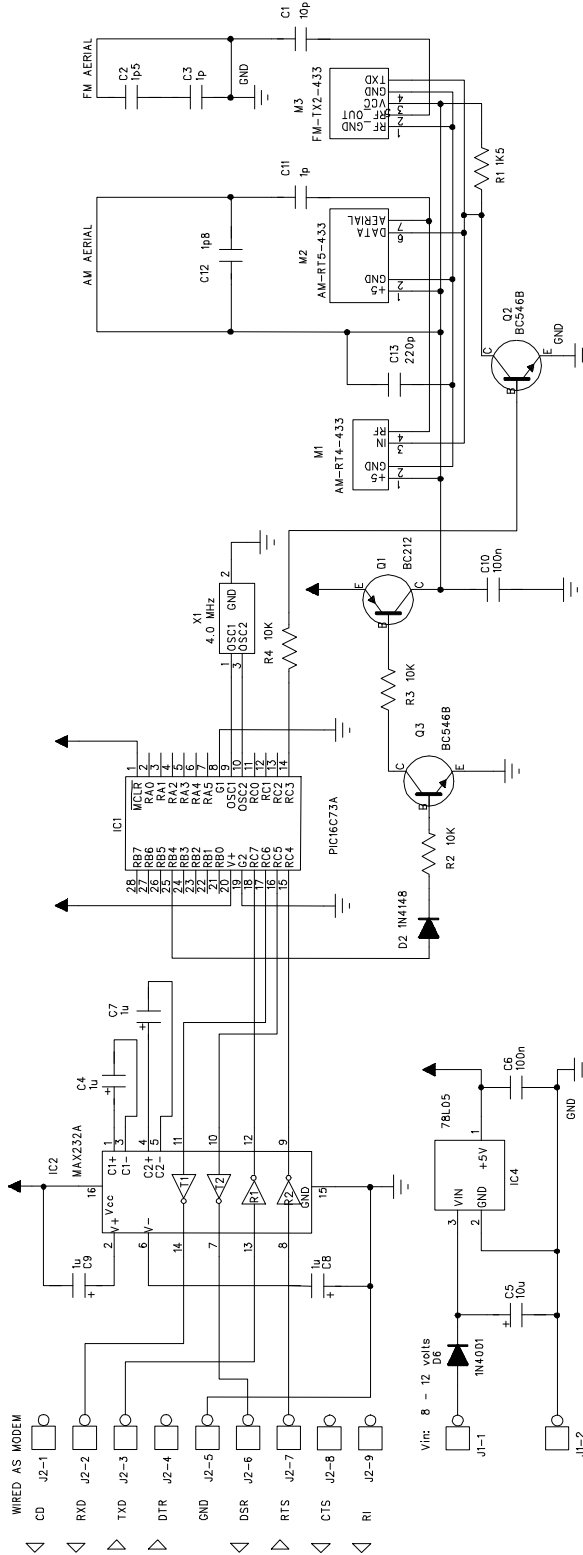| Reference	Value
C2, C3, C4, C6, C7	100nF 2.54mm Pitch Capacitor
C5	10µF 16V Electrolytic Capacitor
D1	1N4001 Diode
IC1	PIC16C73A/P
IC2	MAX232A
IC4	L78L05ACZ
IC7	ULN2803A
J1	2 way screw terminal 5.08mm pitch
J2	9 way D-type female connector
J3	5 way link header
J6, J7, J8, J9	3 way screw terminal 5.08mm pitch
LED2, LED3, LED4, LED5	3mm LED
M1	FM-RX2-433
M2	AM-HRR3-433
M3	AM-RSS2-433
R1	10K ¼ Watt
R3, R4, R5, R6	1K ¼ Watt
RL1, RL2, RL3, RL4	BT47W/6
X1	3 pin resonator - 4.0 MHz

Project #1: Hardware Encoder Circuit Diagram
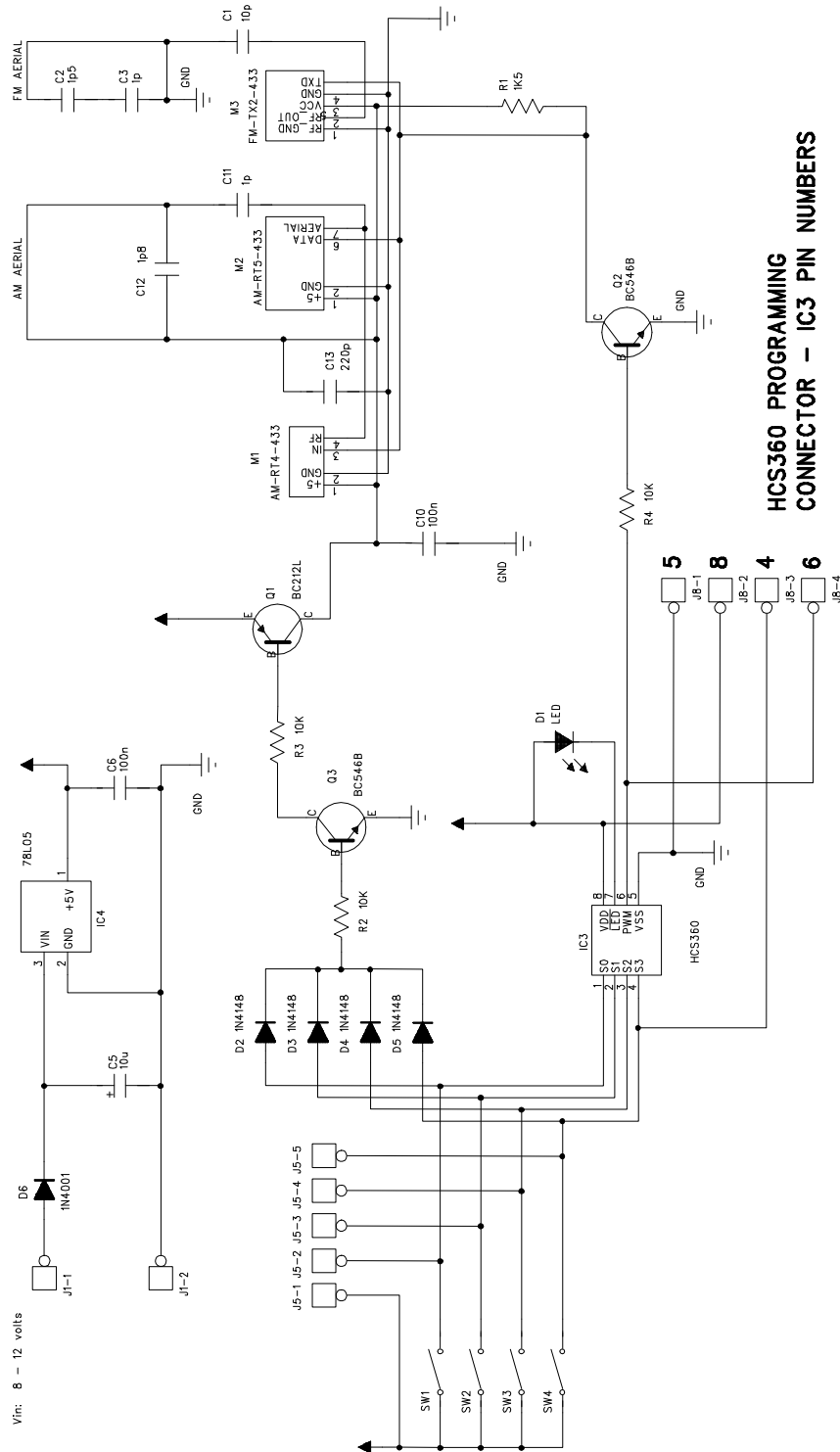
Project #1: Hardware Decoder Circuit Diagram
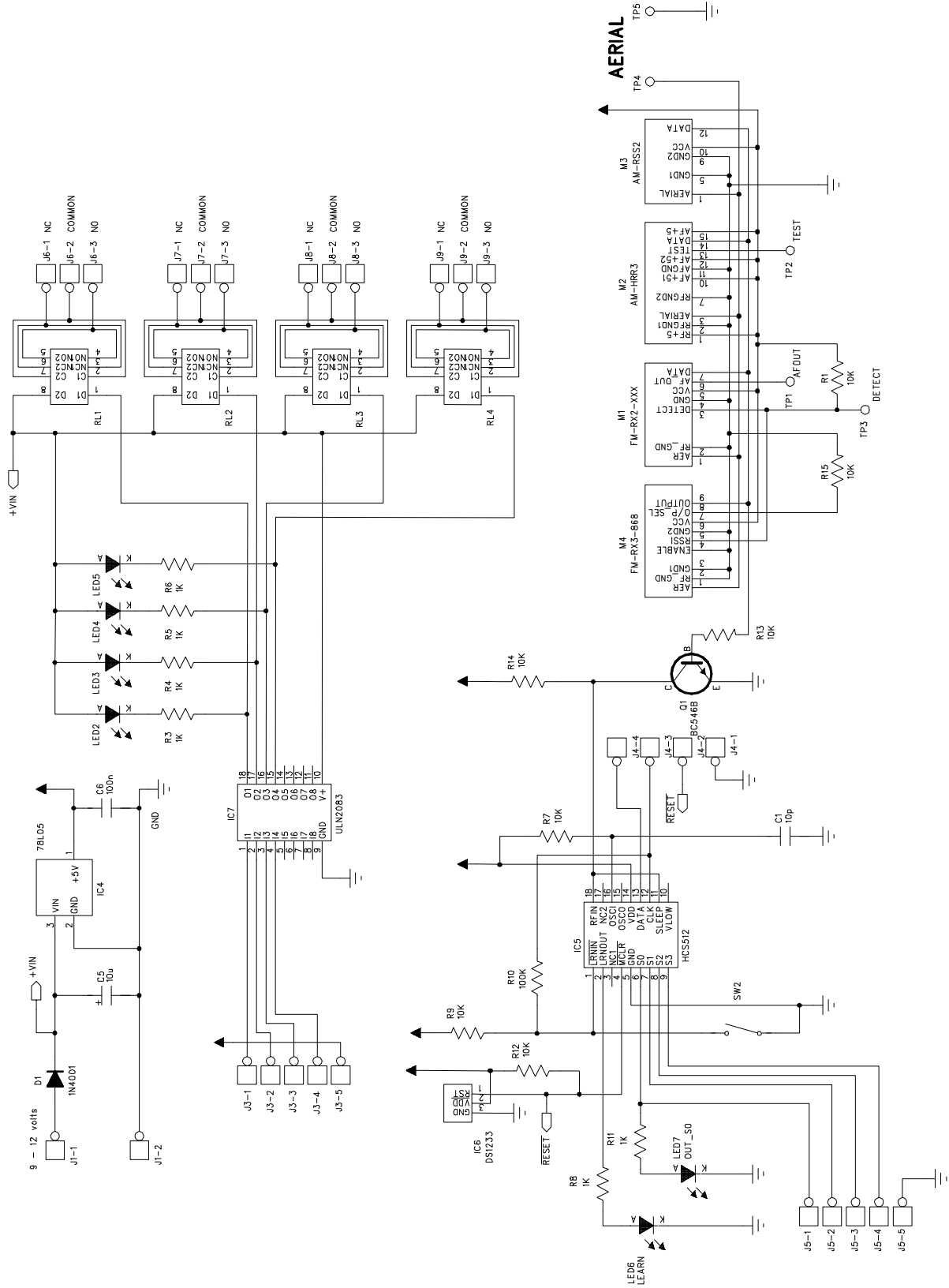
Project #2: Software Decoder Circuit Diagram
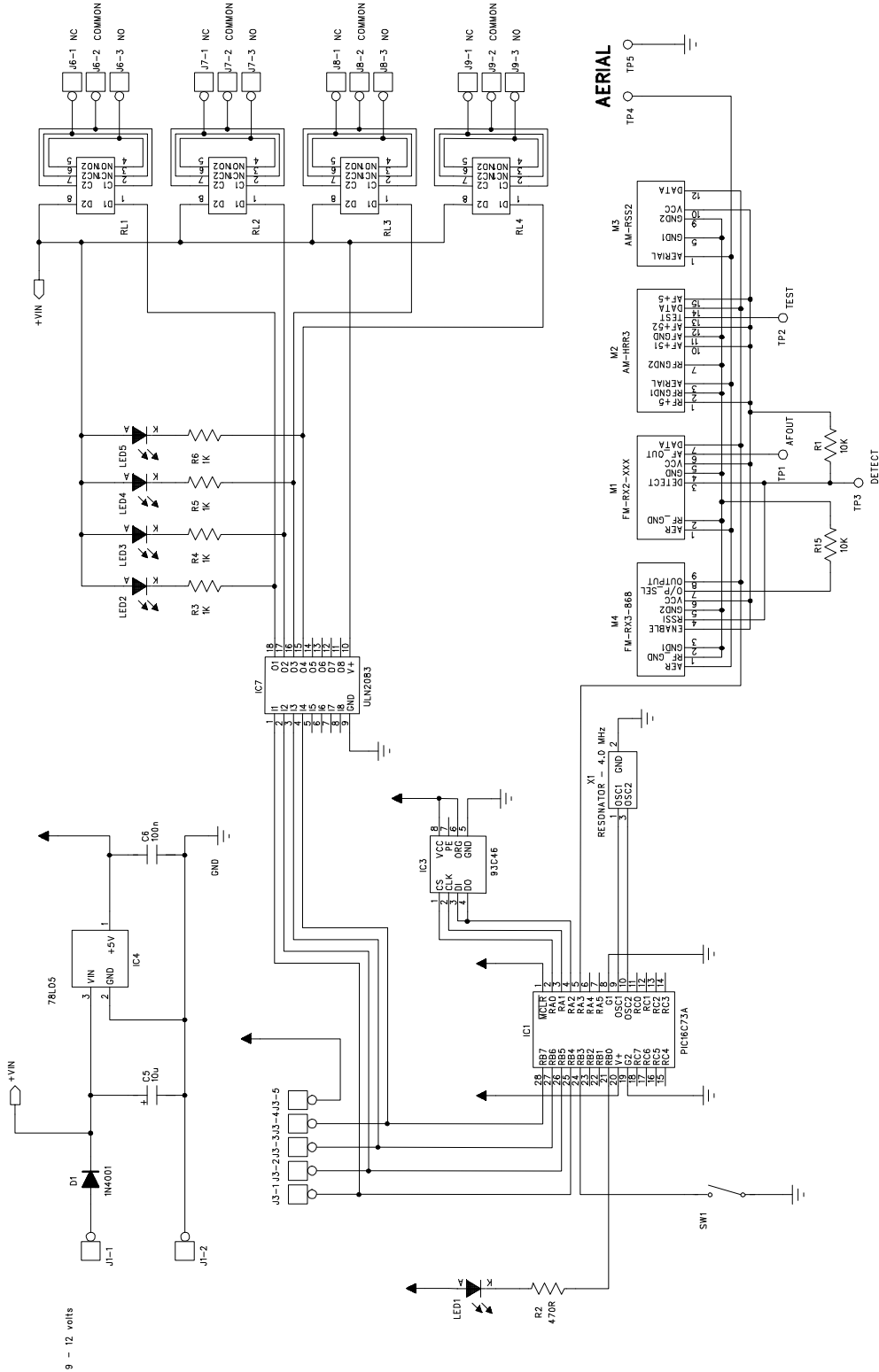
Project #3: Transmitter Data Comms Circuit Diagram

Project #3: Receiver Data Comms Circuit Diagram