TECHNICAL MANUAL

for

Type-II, Type-II+, and Type-III ETOL TRANSPONDERS

Version 2.0

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June 10, 1997

Table of Contents

1.0 Purpose of this Document:

This document is intended to benefit the assembly line worker, repairman, test engineers and others by giving a detailed description of how the Type-II, Type-II+, and Type-III ETOL transponders function, to the component level. It does not seek to describe the ETOL IC nor Vehicle-to-Roadside Communications (VRC) protocol in intimate detail as this information can be found in the below-listed documents as well as others. **It is not intended to be used as a test specification therefore all quantities given should be interpreted as "typical" or "expected."**

The primary focus herein is the Type-II tag with additional sections at the end to describe the design of the Type-II+ and Type-III tags and how these deviate from the Type-II tag.

2.0 Applicable Documents:

Type-II Product Definition Document	PDD #3601 V1.4
Type-II+ Product Definition Document	PDD #3608 V1.3
Type-III Product Definition Document	PDD #3602 V1.4
Type-III JBUS Product Definition Document	PDD #3615 V1.4

ASTM Spec: "Proposed Standard for Dedicated, Short Range, Two-way Vehicle to Roadside Communications Equipment" currently under consideration.

CTS 3601	Component Technical Specification 3601, ETOL Type II Basic Transponder
16203734	IC-ETOL, Electronic Tolling Controller
16209101	Type-II Delco Transponder Schematic Diagram
16236938	Type-II+ H.E.L.P. Transponder Schematic Diagram
16216310	Type-III Delco Transponder Schematic Diagram

3.0 General Description:

The purpose of the Vehicle to Roadside Communications (VRC) System is to respond effectively and cost efficiently to a variety of existing and projected Intelligent Vehicle Highway Systems (IVHS) requirements. The VRC System consists of a roadside communications infrastructure and vehicle transponders (radio frequency identification (RFID)) products supplied by Delco Electronics. This document describes the three basic types of transponders, type-II, type-II+, and type-III.

With a variety of applications and customer needs, it is desirable to develop a flexible and expandable family architecture for the VRC transponder. Such a design provides maximum responsiveness to customer needs with minimum production and developmental costs. At the core of this family of RFID products is the Type-II Basic Transponder. The Type-II designation signifies a read/write transponder with no external host interfaces. This Basic Tag uses active TDMA (Time Division Multiple Access) technology with the ETOL IC as the data link controller and interface.

Simplest among the tag family is the single-board Type-II tag with all its functions controlled by the ETOL IC. With the addition of a small Microchips microprocessor, the tag becomes a Type-II+. The micro modifies the driver signalling to custom specifications. Thirdly, there is the Type-III which is a modified type-II RF board married to a microcomputer board and the driver signalling has been moved from the RF board to the digital board. In addition a RS-232 port on an 8-pin RJ45 connector is incorporated into the Type-III tag. This manual covers all three tag types although the Type-II+ and Type-III are described at the end as mentioned earlier.

4.0 Block Diagram:

Following on the next page is the block diagram depicting the major functional areas of the and Type-II transponders.

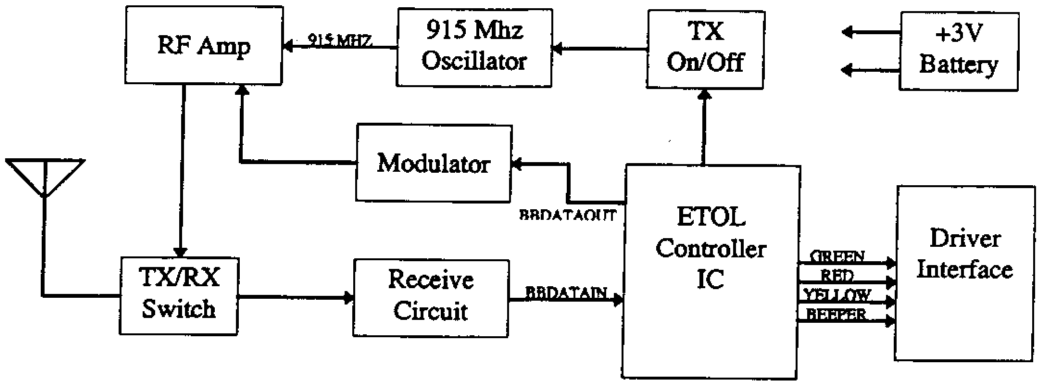


Fig. 1. Type-II Transponder Block Diagram

5.0 Modes of Operation:

The type-II tags can only operate in one of the four following modes, sleep, wakeup, active, and time-out. These modes are mutually exclusive meaning the tag never operates in more than one of these modes at a time. For additional information on the ETOL's various states of operation consult the ETOL IC specification.

5.1 Sleep Mode

The Basic Transponder enters a Sleep mode for 1063 usec when the VRC Function does not detect a possible reader signal. During this mode the VRC Function disables the data detection circuitry, the 4 megahertz oscillator, and all RF circuits to minimize energy consumption and thus prolong battery life. After sleeping for 1063 usec, the VRC Function shall transition the tag to a Wake-Up Mode. (SEE DIAGRAM??)

5.2 Wakeup Mode

During the Wake-Up Mode, the IC's internal 32-Khz timer shall enable only the signal present detection circuitry. If a possible reader signal is detected during this mode, the timer shall transition the transponder to the Reader Control Acquisition Mode. If no signal is detected the transponder shall transition back to the Sleep Mode. The ETOL IC shall remain in the Wake-Up Mode for 57-usec. The first 28.5 usec is dedicated to circuit power-up and stabilization while the second 28.5 usec is used to search for a possible reader RF signal (SEE DIAGRAM??)

5.3 Reader Control Acquisition Mode

Once a valid reader signal is detected, the ETOL chip enters a Reader Control Acquisition Mode (Active mode). In this mode the 32-Khz timer function activates the 4 MHz oscillator and the data reception circuitry in order to receive and decode a valid Reader Control Message (RCM). The first time the ETOL IC detects an RCM, the tag shall transition to the Activation Mode. After the initial RCM reception, the ETOL switches to the Message Slot Mode and begins the transaction during the proper time frame (the ETOL IC also switches to RX and TX Modes during transactions - but this is beyond the scope of this document).

5.4 Time-Out Mode

After the Transponder has successfully processed all of the data slot and activation commands, the ETOL transitions to a Time-Out Mode. During this mode the 32-Khz timer disables the 4 MHz oscillator, all data detection circuits, and any other unnecessary circuits. The length of the time-out is controlled by the reader (and is included in the RCM) and ranges from 0 to 30 seconds. After the reader-specified time-out has elapsed, the transponder returns to the SLEEP mode. The process is now ready to repeat.

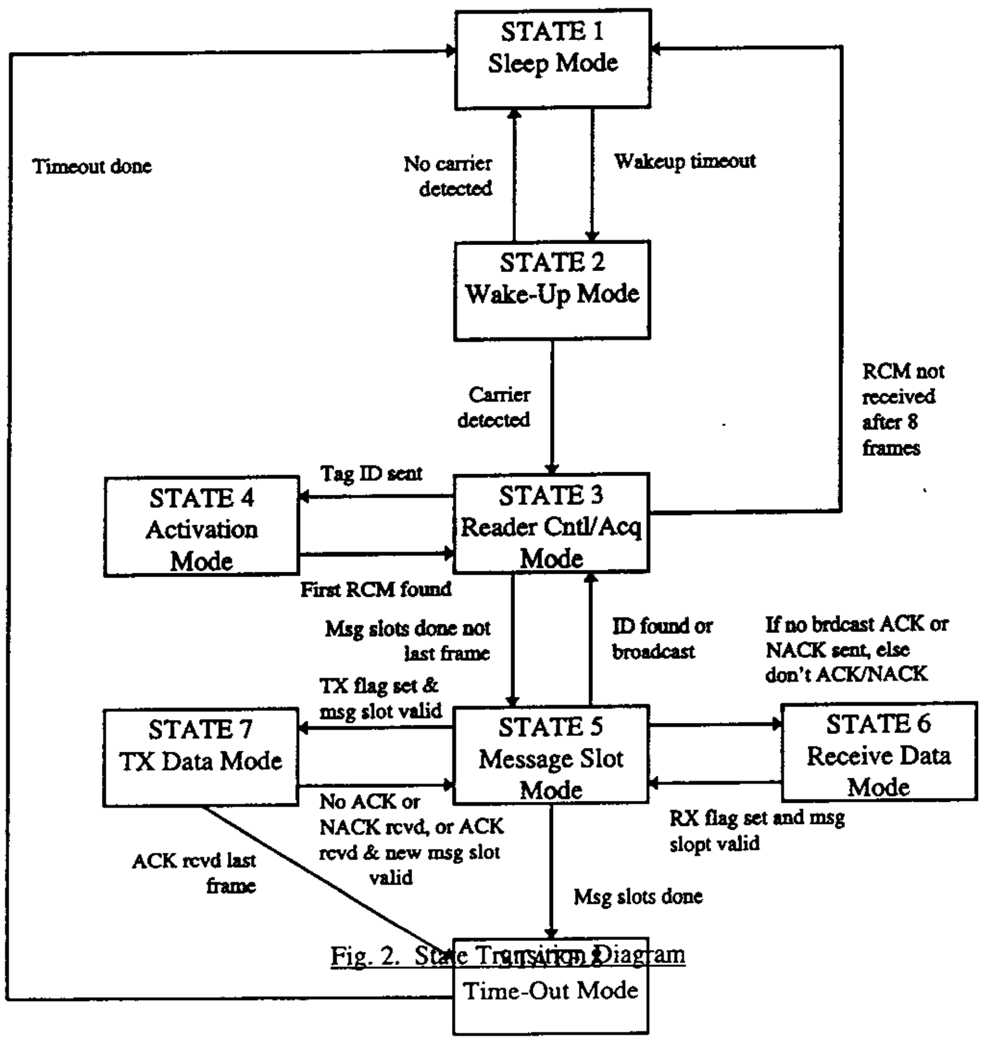


Fig. 2. State Transition Diagram

6.0 Detailed Operation:

What follows is a detailed description of actual circuit operation down to the component level. The reference designators are those found on the appropriate schematic listed at the beginning of this document. And while this document references those designators, the schematic remains as the controlling document should an unforseen discrepancy exist.

6.1 RF Board

6.1.1 Receiver:

The receiver circuit consists of a signal being sourced from the antenna through the TX/RX switch (C6, L2, C7, CR1, CR2, and C8), gigafilter U1, detector diode matching components (L9, L4) detector diode CR3, through the DC blocking capacitor C49 and finally to the BBDATAIN pin of the ETOL IC.

Here are a few pertinent receiver numbers (typical):

Receiver frequency	915 MHz	
Modulation type	Amplitude Shift Keying, (ASK) data at 500 K-bits per second	
Incoming Data Encoding Type	Manchester encoding	
Wakeup Sensitivity:	-35 dBm (35 decibels below one milliwatt)	
Receive Filter Characteristics:	915 ± 9 MHz	atten >= 5 dB
	915 ± 13 MHz	atten >= 10 dB
	915 ± 30 MHz	atten >= 20 dB
	915 ± 65 MHz	atten >= 40 dB

6.1.1.1 Antenna

Early Type-II tags had a quarter-wave "F-type" antenna implemented right on the circuit board copper. It is fed at a point that presents approximately 50 ohms to the transmitter. Later this antenna was refined to look like one section of a shortended dipole with a top hat for capacitive tuning. It has:

Gain:	-1 dBd approx. (decibels below a dipole) or +1 dBi
VSWR	2.0 (Initial design showed 1.1 but this has changed)
Polarization*	Horizontal (the RF field in the vertical polarization is about 7 db lower than the horizontal field.

*The radiated field is horizontally polarized when the tag is oriented right side up in a vertical plane, as it would be when mounted on a semi tractor windshield, for instance.

6.1.1.2 TX/RX Switch

The antenna is then coupled via C5 to the TX/RX switch implemented with CR1, C6, L2, C7, CR2, Q5, and C8. This network operates as a 50-ohm low pass filter in the receive mode and a 50-ohm quarter-wave transformer in the transmit mode. The low pass filter configuration is more a result of implementing the TX/RX switch than it is designing a filter for some particular characteristic.

When in the receive mode the TXOSCON signal (ETOL IC pin 27) is low leaving Q5 in its off state. Therefore the two diodes are without any forward bias and are thus off. Since they have very low junction capacitance very little 915 MHz energy leaks through them. Therefore the incident received RF energy is applied to the 50-ohm gigafilter U1.

When transmitting TXOSCON is high which turns on Q5. This establishes a forward bias current through CR1 and CR2 which creates a low-impedance path for the transmit signal. The even harmonics get dumped through RF-bypass capacitor C8. L2 and C7 block the fundamental 915 MHz and all the odd harmonics while all the even harmonics are shorted out. The next paragraph explains this "quarter-wave transformer action" in greater detail.

Recognize first that this circuit is a discrete version of a shorted quarter-wave transmission line. You will notice that this circuit straddles the pi filter (C6-L2-C7 network) in that CR1 is on the input side of the pi filter and CR2 is on the output side. This allows the pi filter to act as a shorted quarter-wave transmission line during transmit mode with the "far end" of the transmission line shorted by a forward biased CR2. Therefore the input impedance of the transformer is a high impedance to 915 MHz and its odd harmonics but a very low impedance to the even harmonics. The pi filter therefore filters out even harmonics of the transmit signal via this quarter-wave transformer action.

6.1.1.3 Gigafilter

The gigafilter is a 50-ohm, 6mm profile, 3-pole ceramic bandpass filter. It is a MuRata DFC3R914D001BLL with a center frequency of 914.5 MHz, a -0.5 dB bandwidth of 1 MHz, at least 40dB of attenuation at the lower frequency of 869.5 MHz and at least 55 dB of attenuation at the higher frequency of 959.5 MHz (914.5 ± 45.0 MHz). The insertion loss is a maximum of 5.3 dB, but typically 3 or 4 dB. The filter is housed in a metal case which has 4 ground solder tabs in addition to its input and output pins.

6.1.1.4 Matching Network for Diode

The matching network transforms the 50-ohm output impedance of the gigafilter to the high-impedance input (at 915-MHz-type frequencies) of the detector diode.

The matching network to the diode presently consists of inductors L9 and L4 although solder pads have been placed on the board for the possibility of adding capacitors C52 and C50. These might be utilized in future designs to "tweak" or otherwise improve the match.

6.1.1.5 Detector Diode

The detector diode CR3 is a high-speed Schottky RF diode from Hewlett Packard type HPMS-2820. It detects RF energy by simple rectification. So when no RF signal is present the anode of CR3 is sitting at approx. 0.2 V, and when an RF signal is present, the diode easily pulls down the voltage at its anode because the thevinin impedance of its bias network is 18.6K This resulting waveform is AC coupled to the ETOL IC and you have a waveform signal that fluctuates between zero and some small positive or negative level.

6.1.1.6 Detector Diode Bias Network

The detector diode bias network consisting of R12 and R13 is used to forward bias the diode during receive mode. The steady-state voltage at TP9 is about 0.2V, the forward voltage of a Schottky diode. Notice that the cathode of the detector is sitting at DC ground.

6.1.1.7 RF-Bypass

Capacitors C18 and C35 act as RF bypass capacitors to bypass any remaining 915 MHz signal to ground before it gets to the IC. The signal at this point consists only of baseband data i.e. a Manchester-encoded waveform with a 2 usec period and an amplitude range of about 1.8 mVpp to 400 mVpp, with the most positive voltage at 0.2V.

6.1.1.8 DC Blocking Cap

Capacitor C49 blocks any DC voltage from the IC. (The ETOL IC can be DC coupled if the DC voltage applied to this pin is between 0.0 and 0.5V). This blocking cap is needed to keep the diode bias voltage out of the IC (and visa-versa) as well as to keep out the large negative voltage that is generated when strong RF signals are present at the diode. The ETOL IC BBDATAIN pin input impedance is a minimum of 1 Megaohm.

6.1.2 ETOL Control Integrated Circuit

Now that the data has been detected it is presented to the IC for further processing. Part of this processing includes zero-crossing detection, a zero-crossing counter, checksum processing, and other control functions.

Since the details of operation of this IC are classified as "DE CONFIDENTIAL" I will refer the reader to the IC SPEC 16203734 for his or her own referral. Instead, I will give only enough pertinent information below necessary for a technician or engineer to determine the operationality of the tag by what is expected at the various pins.

The ETOL IC provides all the necessary data processing functions that is needed by the tag for the VRC system. The basic functional blocks this IC incorporates are as follows: Not all of these are discussed in this manual.

- Signal Present detection circuitry
- Data Reception circuitry
- Manchester Encoder and Decoder
- CRC Generation and check
- State Machine
- Linear Sequence Generator
- 32 Khz controls (Wake-up Timer, Driver Info)
- Memory (RAM and EEPROM)
- Host Interface and Buffer
- Driver Interface (LEDs and Beeper)

6.1.2.1 32 Khz Crystal

The 32 Khz circuit consists of crystal Y2 and load capacitors C16 and C17. The input pin on the IC is pin 8 and the crystal drive pin is pin 7. This circuit performs all the basic timing functions of the IC and tag. It times the sleep mode, the wakeup interval, the LED flash rate and duty cycle, the beeper sounding rate and duty cycle and the sleep time-out period. This crystal circuit runs all the time, *although it may have a hard time getting started.* (the gain of this circuit block is controlled by the current out of pin 12 and is purposefully kept low to prolong battery life).

Typical voltage waveforms one might expect to see on these two pins are:

Pin 7	OSC32KOUT	300 mVpp	32.768 Khz (or whatever frequency crystal is installed)
Pin 8	OSC32KIN	300 mVpp	32.768 Khz

The ETOL IC spec says that this crystal startup time is a maximum of 10 sec. On older development versions of the ETOL IC, this time could have been longer. It is for this reason that R34 and TP12 have been provided as a means to "kick" start the crystal oscillator circuit. This happens by temporarily grounding TP12 during factory test.

When TP12 is grounded, R34 is placed in parallel with R11 which is the bias current reference resistor. This causes the gain of the internal amplifier in the 32-Khz circuit to increase thereby greatly decreasing the start-up time of this crystal. A tag that doesn't work properly should be checked for a running 32-Khz crystal. If this crystal is not running then perhaps it needs to be "jump-started," (or perhaps it has been dropped and is broken). See troubleshooting section for more details.

6.1.2.2 Base-Band Data In

The incoming data comes in on the BBDATAIN pin (pin 10). When present, it will have a 2 usec period and appear rectangular. Since the data is encoded it may appear like it has missing pulses or double-width pulses but this is just the way Manchester-encoded data looks. The peak-to-peak voltage will of course depend on the strength of the incoming signal but should not be over about 0.80V at a signal level of 0 dBm into the antenna. Here are some typical levels for different power in conditions:

10 dBm	2660 mVpp
0 dBm	800 mVpp
-10 dBm	180 mVpp
-20 dBm	80 mVpp
-30 dBm	20 mVpp

6.1.2.3 4 MHz Crystal

The 4 MHz circuit consists of crystal Y1 and load capacitors C13 and C14. The input pin on the IC is pin 3 and the crystal drive pin is pin 4. This circuit performs all timing functions for the incoming data decoding, clock recovery circuits, and outgoing data encoding. This crystal circuit turns on whenever the signal present detection circuitry activates and remains on for the duration of the transaction.

Typical voltage waveforms one might expect to see on these two pins are:

Pin 4	OSC4MOUT	520 mVpp	4.00 MHz
Pin 3	OSC4MIN	600 mVpp	4.00 MHz

The crystal startup time is specified in the ETOL spec as a maximum of 8 msec.

6.1.2.4 Current Reference

The current reference pin is pin 12. Resistor R11 and decoupler C51 are used to provide the proper bias current reference for the 32 Khz oscillator and input amplifier. A typical voltage to be expected at this pin is:

Sleep mode:	55 mV D.C.
Active mode:	55 mV D.C.

6.1.2.5 Amplifier Gain Compensation

Capacitor C15 provides the compensation for the baseband amplifier inside the IC. The COMP pin is pin 11.

6.1.2.6 Base-Band Data Out

The outgoing data exits the IC on the BBDATAOUT pin (pin 1). It should have a period of 2 usec (as derived from the 4.00 MHz crystal) and appear rectangular. Again, since this data is Manchester-encoded it may appear like some pulses are missing while other pulses are double-width. Peak-to-peak voltage amplitude should be anywhere from 80% to 100% of the voltage appearing on the VBATD pin, (pin 25). Also see the section on the transmitter modulator for additional details.

6.1.2.7 Host Interface

The Host Interface consists of the following 5 pins which are not used in Type-II tags. Their use is reserved for Type-III tags where they comprise the communications link between the ETOL IC and the host microcomputer. Below is given a table including signal state for Type-II applications:

Pin 17	HRXDATA	Output	10K pulldown so tester/programmer can overdrive
Pin 18	INT	Output	N/C
Pin 19	HSCLK	Input	tied to VBATD
Pin 20	CS	Input	tied to VBATD
Pin 21	HTXDATA	Input	tied to VBATD

6.1.2.8 Transmit/Receive Control

TXOSCON (pin 27) is an ETOL IC output that controls whether the tag is transmitting or receiving. When low the tag is in the receive or at least the "RF signal present" mode. When high the tag's oscillator is turned on and the receiver input grounded. After about 60 usec the oscillator stabilizes and the ETOL IC can then send BBDATAOUT information to the RF amp/modulator.

6.1.2.9 ETOL IC Power Pins

Pins VBATA (pin 13), VBATMEM (pin 15), and VBATD (pin 25) supply the power to the various circuit blocks internal to the IC. Type-II tags have these pins all tied to the battery. Capacitors C19, C22, C24, C26 provide a wide range of decoupling/filtering for these power pins.

6.1.2.10 Test Pins

The following pins are for manufacturing test and EEPROM programming only and are not otherwise used in the tag:

TEST_1 pin 26
TEST_2 pin 2
TEST_3 pin 9

6.1.2.11 Zener Zap Pin

This pin should read close to 400 ohms to ground when the ETOL IC is placed on the circuit board. This state indicates that the internal EEPROM memory has been forever protected. The short circuit is an internal short and is not a trace on the circuit board, i.e., the IC's internal EEPROM can never be unprotected by attempting to lift this pin high.

For more information regarding this pin consult the ETOL IC specification 16203734.

6.1.3 Transmitter:

The transmitter is comprised of these 6 functional sub-blocks: the transmitter on/off switch, (not to be confused with the TX/RX switch), oscillator, attenuator, matching network, RF-amp, modulator, and output network. Each of these will be described in the following text.

6.1.3.1 Transmitter On/Off Switch

The network of components Q7, Q8, R20-R23, C1 and C23 perform the duty of supplying +3V power to the oscillator. This transistor switch setup is itself controlled by the TXOSCON signal from the ETOL IC (pin 27) described above.

When TXOSCON goes high Q7 is biased into conduction via R20 and R21. This causes Q7's collector to sink current which in turn causes current flow through the emitter-base junction of Q8. Q8 thereby turns on creating a low resistance path from Q8's emitter to collector. This allows Q8's collector to supply the needed current to the oscillator power rail.

Capacitor C1 bypasses any residual high frequency RF energy (915 MHz and harmonics) to ground while C23 provides lower frequency decoupling for Q8's emitter, the +3V power rail.

The typical rise-time of the oscillator power rail is about 50 nsec.

6.1.3.2 Oscillator

The oscillator is comprised of transistors Q3 and Q4 (Siemens BFP-183), U2 (RFM SAW, RP1094), and a few sundry bias/bypass components described below. U2 is a 2-port quartz Surface Acoustic Wave (SAW) integrated circuit resonator designed for resonance at 915 MHz. Q3 and Q4 provide enough gain to overcome the insertion loss of the resonator with enough left over to drive the downstream attenuator load. Transistor Q4's dual emitters are grounded directly whereas Q3's emitters are degenerated with R7 to provide oscillator stability. Capacitors C46 and C47 bypass Q3's emitters at high frequencies while R6 sets the bias point of Q4. R5 limits the collector current of Q4 while L3 allows the AC signal at Q3's collector swing above and below +3V. C10 and C11 stabilize the oscillator power rail by providing a shunt to any residual high frequency energy. Finally, capacitor C32 couples the oscillator signal energy to the attenuator ("pad") which then feeds the RF amp.

The oscillator's output power is about +6 dBm while pulling 47 mA. This is with both the RF oscillator and amplifier on. Individually they pull 36 mA and 11 mA respectively. Its startup time is about 10 usec.

6.1.3.3 Attenuator

R28, R29, and R30 (75/120/75 ohms respectively) comprise the 14 dB attenuator or "pad". This circuit sub-block is used to isolate the oscillator from the loading effects of the modulator/RF amp while maintaining a relatively constant and equal input and output impedance. A pi-network can perform this task by its unique circuit configuration and is easily verified by quick analysis. A simple 2-resistor voltage divider does not have an equal input and output impedance.

6.1.3.4 Matching Network

C9 and L8 form an L-network which optimally matches the 50-ohm output impedance of the pi attenuator to the input of the transistor. This method provides for maximum gain while still assuring unconditional circuit stability.

6.1.3.5 RF Amp

Transistor Q2 is the heart of the RF amp configured in a common emitter configuration and provides about 12 dB of gain. Absolute output power from the amp is about +4.5 dBm at +3.0V, assuming a 50-ohm load. Its bias point is set up by R4, R19, and R31. R32 provides emitter degeneration while C48 and C53 bypass the RF around R32 to ground. In the collector circuit is L6 with the power supply end of L6 stabilized by C2. Output AC coupling is provided by C4.

A quick tabulation of the three gain stages yields:

oscillator power gain:	+6 dBm
attenuator loss:	-14 dB
RF amp power gain:	+12 dB

RF-amp output level at +3V:	+4 dBm

6.1.3.6 Modulator

Modulation is accomplished by turning on and off power to the RF amp. The control signal that accomplishes this is BBDATAOUT originating from the ETOL IC pin 1. BBDATAOUT is a digital Manchester-encoded waveform representing a string of bits from the IC. The modulation that results is

Amplitude Shift Keying (ASK) modulation. The circuit elements that comprise this are Q1, R2, R3, C3, and C31. When BBDATAOUT is high, transistor Q1 is cutoff thus Q1's collector is 0 volts. Therefore no RF signal is presented to the antenna. Likewise when BBDATAOUT is low, Q1 is biased into conduction via base divider R2 and R3, Q1 conducts providing +3V power to the collector of Q1. A signal can now be delivered to the antenna The oscillator does not turn on and off with BBDATAOUT but runs continuously until TXOSCON causes it to shut off. Since the RF amp in its off state is not a perfect signal block a small amount of RF energy will leak through. A typical ratio of power out when transmitting a 1 to power out when transmitting a 0 is about 23 to 25 dB. The specification is at 20 dB or greater. (Some of the "off" power may be simply radiating off the tag from the oscillator making the spec more difficult to achieve).

6.1.3.7 Output Network

The output network consists of C4, C5, C29, C30, R35, and CR1. This couples energy from the output of the RF amp to the antenna. It must be noted that this circuit was originally intended to accommodate a pi filter network for filtering of the fundamental mode signal, however it was determined that this filter was not needed after all. However, the solder pads for this network were left just in case they were needed at some future time. That is why the 95 transponder assembly dictates that C29 and C30 not be installed and R35 be a 0-Ω resistor. The RF energy travels on through the forward biased CR1 (see earlier explanation), through coupling capacitor C5 to the antenna.

6.1.4 Power Supply

The power for the tag is provided by a 3V lithium battery, Sanyo type CR17450E-R with a Delco-derated capacity of 1700 mAH. The battery has solder tabs to accommodate wires that are themselves soldered directly onto the circuit board at J1, thus eliminating mechanical connections. J1-1 is the positive terminal and J1-2 is the negative or ground terminal.

6.1.5 Driver Interface

The Type-II driver interface uses an on-board audible beeper and three LEDs to signal the driver. These components are LEDs CR4, CR5, CR6 and beeper U4. While beeper U4 is driven directly by pin 22 of the ETOL IC each LED has its own drive circuitry.

The green LED, CR4, is switched by Q9 with diode current limited to about 5.7 ma by R16. Resistor R24 provides for positive shutoff of Q9 and the LED since the LED outputs of the IC are open-drain PMOS transistors which are only able to ***source*** current. These pins cannot ***sink*** any current. The most that can be sourced and still retain adequate voltage is about 4 ma. When the LED1 pin of the ETOL IC (pin 24) is high the LED is on. When low the LED is off.

The circuits for the red LED (CR6) and the yellow LED (CR5) operate in a similar fashion with the exception that ETOL IC pin 23 labeled LED2 controls the red LED and pin 16 labeled LED3 controls the yellow LED. Current draw for the yellow LED is about 10.3 mA and for the red LED is about 3.3 mA.

The operation of the LEDs and beeper are independent. So any beeper signal can be given with any LED condition. The duration of all signals is 5 seconds, dead time included. The LED outputs are high for 5 seconds. The beeper signal is active for 2 seconds, followed by 3 seconds of dead time. No new signals can be set until the previous signal is completed.

The beeper can be in an off , confirmation, or warning mode. The off mode is self-explanatory. The beeper confirmation tone is an intermittent pulsed 4096-hz tone with a total duration of 2.0 ± 0.1 sec. This tone consists of four chirp tones. Each chirp tone shall have a period of 0.5 seconds and a duty cycle of 50%. The warning or "negative confirmation" tone is a continuous 4096-hz (32,768/8) tone with a total duration of 2 ± 0.1 seconds.

7.0 Debug Procedures:

Often times in debugging an electronic device a simple visual inspection will yield the answer. Such manufacturing shortcomings as solder bridges, cold solder joints, incorrect component, incorrect component orientation, cracked, broken, or "tombstoned" component, contamination on board (especially high impedance nodes), etc., can often be the source of the trouble. Other cases may require identifying the proper failure mode before an efficient means of tracking down the faulty component can be realized.

In any case there are 3 or 4 basic tests that should be performed on any faulty tag before any further debug work is performed. These are:

Visually inspect the unit
Check the battery voltage
Check both the 32 Khz and the 4 MHz crystal oscillator output pins, (pins 7 and 4 respectively).

The oscillator output pins can be checked by a high impedance VOM set to measure an AC voltage.

Another check that yields much information is checking the tag/reader communications link with a spectrum analyzer. With the analyzer set for a f_0 = 915 MHz, a span of 0 MHz, and full resolution bandwidth one can view the messages from the reader and any response from the tag. Thus you can immediately tell whether or not the reader and/or the tag is radiating, and if so, if it is radiating properly. If it is found that spurious or weak emissions are present in the transmission then this could very well be the cause of the problem. It would then be left to the simple task of determining which device, the reader or the tag is at fault.

Following are listed several common symptoms and the possible causes.

7.1 Common Symptoms:

Tag does not wake up:

This symptom is confirmed by the amount of current the tag draws. When in the sleep mode it draws about 15 uA. When in the acquisition mode it draws perhaps 100 to 150 uA and when fully awake and talking to the reader it draws about 2, 3, or 4 mA on the average. The tag does not transmit any signal in the sleep or acquisition modes. This symptom can also be at least partially verified by the fact that the 4-MHz crystal never starts, (unless, of course, that circuit is faulty).

Incorrect battery voltage	Check battery voltage-should be 2.4 - 3.3 V
Reader transmit signal strength too weak	Bad cable/interconnects somewhere in signal path. Check transmit signal levels at tag with spectrum analyzer In line attenuator improperly set or set too high Test setup/coupler improperly calibrated
Reader improperly configured	Check reader setup parameters, cable connections, etc. reset reader
32 Khz oscillator dead	Jump start the crystal by momentarily grounding test point TP12 at R34. (See 32 KHz section) Check for solder bridges around crystal circuit Replace the crystal Check that load caps C16 and C17 are correct Replace IC
Tag is actually waking up but you just don't know it because the tag doesn't transmit anything back to the reader.	Check current draw to verify mode then look at other troubleshooting areas including "faulty transmitter" section.
4 MHz oscillator dead	Check for solder bridges around crystal circuit Replace the crystal Check that load caps C16 and C17 are correct Replace IC
Reader transmit frequency incorrect	Check that reader transmit frequency is 915 MHz ± approx. 300 Khz
Bad solder joint or solder bridge somewhere in circuit	Visually inspect all solder joints for good flow and shiny surface under well-lit high power magnifying glass.
Improper component or incorrect component value	Visually compare components against known good unit
Cracked or broken component	Check all components under a lighted high-power magnifying glass

Tag wakes up but sensitivity is degraded:

This symptom is verified by the tag working but only when the reader signal strength to the tag is increased.

Incorrect battery voltage	Check battery voltage-should be 2.4 - 3.3 V
Weak transmit signal	Bad cable/interconnects somewhere in signal path; check transmit signal levels at tag with spectrum analyzer

Monitoring instrument giving erroneous reading	Check all cables, interconnects, couplers, etc., between monitoring point and instrument.
Incorrect circuit component(s) in receive path	Replace all components in receive path taking care to determine which component is at fault. This problem could occur again if a machine is set up with the wrong part or if a vendor shipped the wrong part, etc.
Interferring signals	Track down and eliminate or else shield
Bad solder joint or solder bridge somewhere in circuit	Visually inspect all solder joints for good flow and shiny surface under well-lit high power magnifying glass.
Incorrect component or incorrect component value	Visually compare componens' size and color against known good unit
Cracked or broken component	Check all components under a lighted high-power magnifying glass
Reader transmit frequency is incorrect	Check that reader transmit frequency is 915 MHz ± approx. 300 Khz

Tag wakes up but does not transmit:

This symptom is verified by again looking at tag current draw to determine it is in a mode that demands at least about 150 uA and up to about 2 - 4 mA depending on the failure mode. Another way is too verify that the 4-MHz oscillator circuit is turning on and off. The fact that the tag does not transmit can also be determined by observing the communications link activity on a spectrum analyzer and noting the tag's missing responses.

Incorrect battery voltage	Check battery voltage-should be 2.4 - 3.3 V
RF oscillator is not being commanded on	U3-P27 never goes high Q8 collector never goes high Check transmitter on/off function in detail as described in the text. Replace IC
Oscillator doens't work	SAW could be broken Incorrect part Check for solder bridges, splashes in osc. circuit
BBDATAOUT pin stuck low or high	Check for solder bridges, splashes Replace IC Reset IC by temporarily shorting pins 25 and 26
No power to RF amp	Q1's collector never goes high Check modulator circuit
TX/RX switch not functioning properly-stuck in receive mode	Check transmitter on/off function as described below
Solder bridges, splashes in transmitter and/or oscillator circuit.	Inspect both sides of board for solder nonconformity. Could be underneath component hidden from view.
32 Khz oscillator dead and tag is in reset mode (This could potentially happen after the battery is first applied).	Jump start the crystal by momentarily grounding test point TP12 at R34. (See 32 KHz section) Check for solder bridges around crystal circuit Replace the crystal Check that load caps C16 and C17 are correct Reset IC by temporarily shorting pins 25 and 26 Replace IC

Bad IC	Replace U3
Bad solder joint or solder bridge somewhere in circuit	Visually inspect all solder joints for good flow and shiny surface under well-lit high power magnifying glass.
Incorrect component or incorrect component value	Visually compare components' size and color against known good unit
Cracked or broken component	Check all components under a lighted high-power magnifying glass

Tag transmitting continuously:

Tag is in reset mode (This could potentially happen after the battery is first applied).	Reset IC by temporarily shorting pins 25 and 26
32 Khz oscillator dead	Jump start the crystal by momentarily grounding test point TP12 at R34. (See 32 KHz section) Check for solder bridges around crystal circuit Replace the crystal Check that load caps C16 and C17 are correct Replace IC
U3-P27 stuck high	Check for solder bridges along U3-P27 trace. Fault could be underneath a component.
Q1's collector stuck high	Check BBDATAOUT pin (U3-P1), should not be stuck low. If so check modulator (Q1) circuit.
Bad solder joint or solder bridge somewhere in circuit	Visually inspect all solder joints for good flow and shiny surface under well-lit high power magnifying glass.
Improper component	Visually compare components' size and color against known good unit
Cracked or broken component	Check all components under a lighted high-power magnifying glass

Tag transmit power weak:

Low battery voltage	Check battery voltage-should be 2.4 - 3.3 V
Battery statically OK but dips low when transmitter on	Check battery voltage under a 50-ohm load, should not drop less than about 2.4V
TX/RX switch not functioning properly	Check to make sure diodes CR1 and CR2 have proper forward bias (0.8 or so volt) when transmitter is commanded on.
Modulator not switching fully on	Check U3-P1 for full 0 to VBAT swing Check Q1's collector for near full swing. Check bias network for proper component value and voltage swing; should swing between VBAT and VBAT-.75V) Faulty Q1-replace it.
RF amp not biased properly	Check for proper Q1 bias voltage: 0.79V without data
Bad solder joint or solder bridge somewhere in circuit	Visually inspect all solder joints for good flow and shiny surface under well-lit high power magnifying glass.
Incorrect component or incorrect component value	Visually compare components' size and color against known good unit
Cracked or broken component	Check all components under a lighted high-power magnifying glass

No LEDs Light:

Low battery voltage	Check battery voltage-should be 2.4 - 3.3 V
LEDs are all in backwards	Check orientation per assembly print. Also check assembly process/machine setup, etc.
LEDs not being commanded on by IC	Other faulty circuit block Faulty ETOL IC-U3
Incorrect component or component value	Check to make sure transistors Q9-Q11 are the proper type and value Check R16, R17, and R18 for proper value Check R24, R25, and R26 for proper value Check machine setup, part numbers, shipping labels, etc. to see if wrong components are being installed
Other faulty circuit blocks	Identify other concurrent symptoms and continue to better diagnose the problem.
Bad solder joint or solder bridge somewhere in circuit	Visually inspect all solder joints for good flow and shiny surface under well-lit high power magnifying glass.
Incorrect component or incorrect component value	Visually compare components' size and color against known good unit
Cracked or broken component	Check all components under a lighted high-power magnifying glass

A Particular LED Doesn't Light:

Low battery voltage	Check battery voltage-should be 2.4 - 3.3 V

Blown LED	Replace LED
Bad switch transistor	Replace faulty Q9, Q10, or Q11, depending on which circuit is faulty.
LED in backwards	Check orientation per assembly print
LEDs not being commanded on by IC	Other circuit blocks are potentially at fault Identify other symptoms and continue to better diagnose the problem.
Shorted ETOL IC output pins	Inspect board for solder bridges, splashes, etc. Faulty IC-replace it.
Bad solder joint or solder bridge somewhere in circuit	Visually inspect all solder joints for good flow and shiny surface under well-lit high power magnifying glass.
Incorrect component or incorrect component value	Visually compare components' size and color against known good unit
Cracked or broken component	Check all components under a lighted high-power magnifying glass

Beeper Doesn't Sound:

Incorrect battery voltage	Check battery voltage-should be 2.4 - 3.3 V
Beeper isn't commanded by IC to beep!	Other circuit blocks are potentially at fault Identify other symptoms and continue to better diagnose the problem.
Faulty beeper	replace beeper
BEEPER output pin stuck low.	Check for solder bridges Replace BEEPER Replace IC
Bad solder joint or solder bridge somewhere in circuit	Visually inspect all solder joints for good flow and shiny surface under well-lit high power magnifying glass.
Incorrect component or incorrect component value	Visually compare components' size and color against known good unit
Cracked or broken component	Check all components under a lighted high-power magnifying glass

Transmitter Frequency Incorrect:

Incorrect battery voltage	Check battery voltage-should be 2.4 - 3.3 V
Incorrect SAW component installed	Check part number per assembly print
Bad SAW filter	Replace SAW
Wrong component in oscillator section	Check components Q3, Q4, R6, R7, C46 and C47 per assembly prints
Solder bridge, cold solder joint, etc.	Visually inspect the board on both sides. Also use ohmmeter to check for "invisible" shorts
Measurement taken too quickly after startup.	Make sure instrument doing the measuring waits long enough for the oscillator to stabilize before taking a reading. Typical time is 20 usec
Bad solder joint or solder bridge somewhere in circuit	Visually inspect all solder joints for good flow and shiny surface under well-lit high power magnifying glass.

Incorrect component or incorrect component value	Visually compare componens' size and color against known good unit
Cracked or broken component	Check all components under a lighted high-power magnifying glass

Tag battery drains quickly:

Tag continuously transmitting	Check TX/RX circuit to make sure tag is not stuck in CW (continuous wave) transmit mode.
Short on board causing excessive current drain look for solder splashes	Inspect circuit board board for solder bridges Use a sensitive voltmeter to look for voltage drops along traces. This will indicate short location.
Faulty component causing excessive current drain	Feel around the circuit board for faulty components that might be warm or hot. Replace those components. Use an infrared temperature sensor to look for a warm or hot part. Replace component. Use a sensitive voltmeter to look for voltage drops along traces. This will indicate short circuit locations.
Bad battery itself	Replace battery Check other batteries to see if any else are bad. Could be a bad lot of parts in this case
Bad solder joint or solder bridge somewhere in circuit	Visually inspect all solder joints for good flow and shiny surface under well-lit high power magnifying glass.
Incorrect component or incorrect component value	Visually compare components' size and color against known good unit
Cracked or broken component	Check all components under a lighted high-power magnifying glass

7.2 Typical Voltages:

The following table gives some typical values that can be expected in a working system. These values are not intended to reflect actual manufacturing test limits but are given instead to help the repair person diagnose a faulty tag.

FUNCTIONAL BLOCK	LOCATION	NAME/FUNCTION	CHARACTERISTICS (approximate)
Receiver:	**These characteristics apply when the tag is in the receive mode**		
	Q5 collector	T/R switch driver	should be 2.1V or so (This value is not VBATD because of some small amount of leakage through the PIN diodes
	CR1 anode	Upper PIN diode	3.0V (VBATD)
	CR2 anode	Lower PIN diode	should be between 2.5V or 2.6V
	ETOL IC pin 10	BBDATAIN	0.6 mVpp - 400 mVpp digital bit stream at 500 Kbs (kilo bits/sec) when receiving data. DC value is 1.4V whether receiving or transmitting
	ETOL IC pin 14	RXDATAON	equal to or slightly less than battery voltage when in receive mode. Otherwise low.
	ETOL IC pin 27	TXOSCON	approx. 0.0V when in receive mode. Otherwise high (at or very near VBATD)
ETOL IC:	**These characteristics are independent of the tag operating mode**		
	Pin 7	OSC32KOUT	32.768 KHz sinewave 0.3Vpp
	Pin 8	OSC32KIN	32.768 KHz sine 0.3Vpp
	Pins 13, 15, 25	VBAT[A, MEM, D]	battery voltage-VBAT
	Pin 6	VSS	ground-0 volts
	Pin 5	ZNR_ZAP	0.0V
	These characteristics are applicable during the tag reader control and activation modes		
	Pin 3	OSC4MIN	4.00 MHz sine, 0.60Vpp
	Pin 4	OSC4MOUT	4.00 MHz sine, 0.52Vpp
Transmitter:	**These characteristics apply when the tag is in the data transmit mode**		
	CR1 anode	Upper PIN diode	1.75V
	CR2 anode	Lower PIN diode	0.95V
	Q7 collector	Osc. turn-on switch	0.15V typical, range is 0.0 - 0.2V
	Q8 collector	oscillator supply rail	2.85 typical value but not less than about 0.3V below battery voltage, VBAT.
	ETOL IC Pin 1	BBDATAOUT	3Vpp (or whatever battery voltage is) digital bit stream at 500 Kbs

	Q1 base	modulator	Shape similar to BBDATAOUT but voltage fluctucates between 2.2. and 3.0V
	Q5 collector	T/R switch driver	0.15V typical, range is 0.0 to 0.2V
	Q1 collector	modulator	Should look like an inverted BBDATAOUT signal with slightly less voltage peak (VBAT - 0.2V or so)
	Q3 collector	oscillator output	Looks like Q1 collector as the 915 Mhz component is not visible with an oscilloscope.
Driver Interface:	**The signals below become active when the ETOL IC has information to send to the driver.**		
	Q9, Q10, Q11 collector	+3V	constant battery voltage VBAT
	Pin 24	LED1 (GREEN) on/off signal	off: 0.0V / on: VBAT-0.05V or so
	Q9 emitter	GREEN LED	off: 0.0V / on: 2.2V
	CR4 cathode	GREEN LED	off: 0.0V / on: 0.39V
	Pin 23	LED2 (RED) on/off signal	off: 0.0V / on: VBAT-0.05 or so
	Q10 emitter	RED LED	off: 0.0V / on: 2.2V
	CR6 cathode	RED LED	off: 0.0V / on: 0.6V
	Pin 16	LED3 (YELLOW) on/off signal	off: 0.0V / on: VBAT-0.05V or so
	Q11 emitter	YELLOW LED	off: 0.0V / on: 2.2V
	CR5 cathode	YELLOW LED	off: 0.0V / on: 0.4V
	Pin 22	BEEPER on/off	off: 0.0V / on: VBAT-0.05V or so, 4KHz square wave

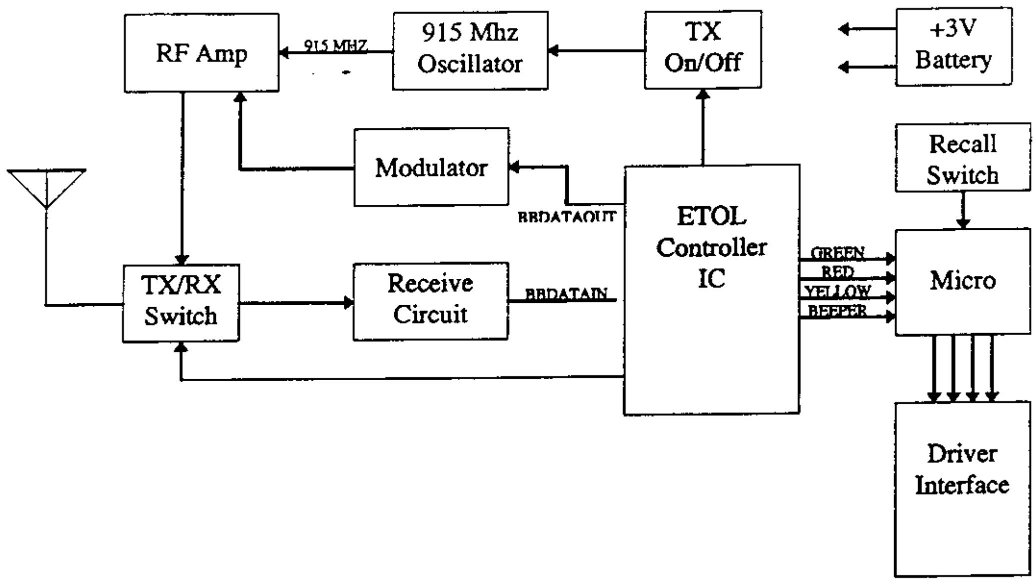


Fig. 3. Type-II+ Transponder Block Diagram

8.0 Block Diagram for Type-II+ Transponder

Shown above is the block diagram depicting the major functional areas of the Type-II+ transponder. Note the addition of the microprocessor between the ETOL IC and the driver interface. This allows the ETOL IC's standard driver signalling to be modified by the micro, and the implementation of a recall switch to recall the current message.

The 3 LED signals are routed directly to inputs of the Microchips PIC16CR58A. The red LED is routed to pin 19, the green to pin 20, and the yellow to pin 1. The beeper signal does not because the micro can generate this according to what color signal the micro receives. When the micro detects a high on one of these lines it wakes up and generates a corresponding signal to that color LED. The red LED output pin is pin 7, the green LED output pin is pin 8, and the yellow LED output pin is pin 9. The length and duty cycle of the LED signal is left up to the program in the micro. For each color of LED the micro generates some beeper signal which is output on pin 10. The micro drives the 3 LEDs and beeper directly so no drive transistor is needed. The current limiting resistors for the LEDs have been chosen such that the LED current replicates that of the Type-II transponder.

After the micro has completed its signalling message the recall button may be depressed to activate it again. This control signal activates the MCLR* pin (pin 4) on the micro, which causes it to wake up and display the last message again.

The micro is clocked by an R/C oscillator at pin 18 and operates at about 130KHz. Power (+3V) is fed into pins 15 and 16 with pins 5 and 6 as the grounds. Pin 3 is also grounded and pins 2, 11, 12, 13, and 17 left as no connects.

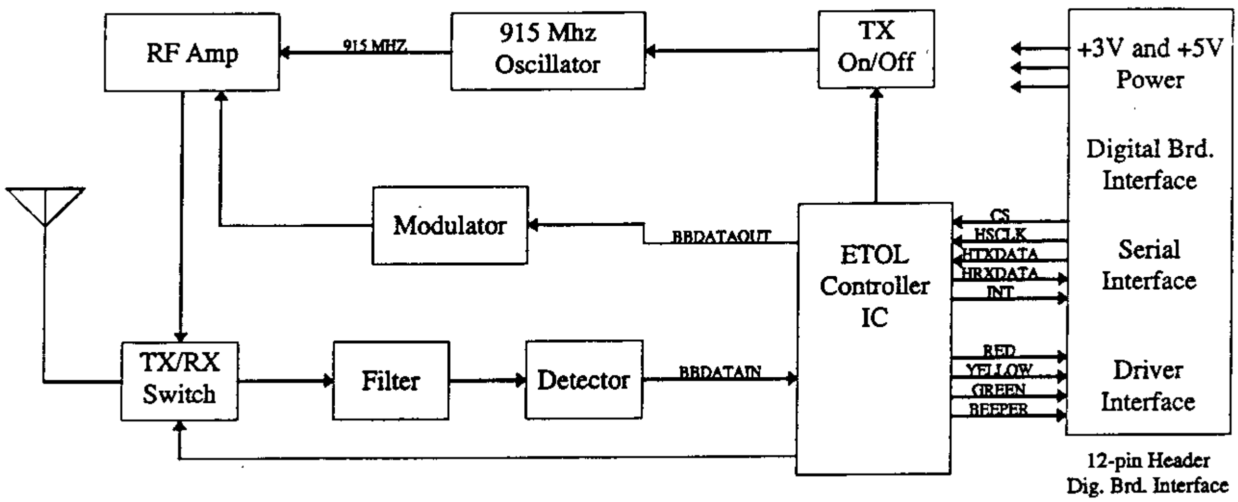
For detailed information concerning the signalling consult the Type-II+ PDD mentioned at the beginning of this document.

8.1 Typical Voltages for Type-II+ Transponder:

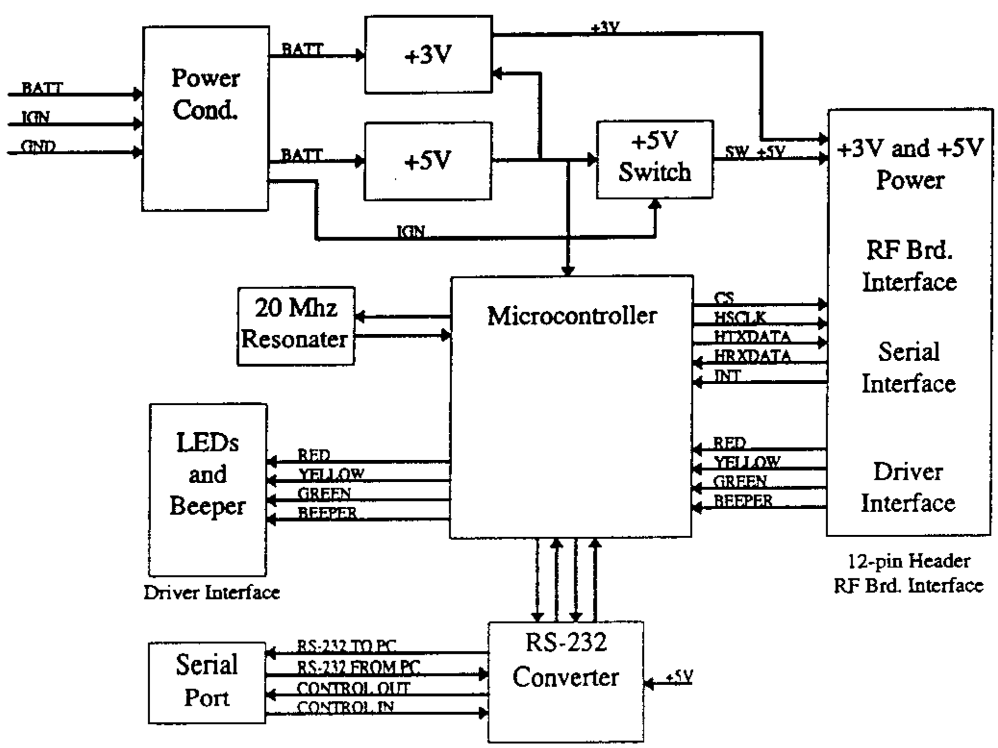
The following table gives some typical values that can be expected in a working system. These values are not intended to reflect actual manufacturing test limits but are given instead to help the repair person diagnose a faulty tag.

FUNCTIONAL BLOCK	LOCATION	NAME/FUNCTION	CHARACTERISTICS (approximate)
	The characteristics listed here are in addition to those listed for the standard Type-II tag		
	U5-P15, -P16	VDD +3V supply for U5	+3V
	U5-P5, -P6	VSS power returns	0V
	U5-P18	CLK R/C oscillator pin	3.0V when inactive 0.8V - 2.0V, 14.2KHz sawtooth when active
	U5-P19	RED_IN red LED signal	0V when inactive 3V when active
	U5-P20	GREEN_IN green LED signal	0V when inactive 3V when active
	U5-P1	YELLOW_IN yellow LED signal	0V when inactive 3V when active
	U5-P4	MCLR* recall switch	3V when inactive 1V to 3V R/C curve when active; could have multiple R/C cycles
	U5-P7	RED_LED red LED driver pin	0V when inactive 2.7 V when active
	U5-P8	GREEN_LED green LED driver pin	0V when inactive 2.5V when active
	U5-P9	YELLOW_LED yellow LED driver pin	0V when inactive 2.0 V when active
	U5-P10	BEEP_CONT beeper driver pin	0V when inactive 3Vpp square wave when active
	U5-P2, -P17, -P11 -P12, -P13	N/C	Don't care

Type-III Transponder



RF Board



Digital Board

9.0 Block Diagram for Type-III Transponder

Shown above is the block diagram depicting the major functional areas of the Type-III transponder. The driver signalling has been moved from the RF board to the digital board where, like in the Type-II+ case, the micro has been given control over driver signalling. In this way the micro can be programmed for any variety of driver signalling that is desired. Transistors Q1, Q2, and Q3 are the drivers for the green, yellow, and red LEDs respectively.

In addition to this feature there is a RS-232 port on a J45 8-pin connector. The interface is a 4 wire type with signals DATA_IN, DATA_OUT, CONTROL_IN and CONTROL_OUT and, of course, ground. This function is provided to us courtesy of National Semiconductor with their 16-pin DS14C232TM chip.

The Type-III derives its power from the vehichle battery via a 12-conductor power harness consisting of +12V, IGN, GND, and SHIELD. A National LT2951CN +5V regulator on the digital board regulates the voltage for the Texas Instrument TMS-370C756AFNT micro and its associated circuitry. The RF board uses a switched version of this +5V supply for the RF amplifier on the front end of the receiver. IGN is used to switch it on and off. A second regulator on the digital board, consisting of a single transistor and 2 resistors provides primary power for the RF board. This is a +3V regulator where the temperature characteristics are exploited to compensate for transmit power degradation over the specified temperature range.

The micro's clock is driven by a 20.0 MHz resonator sitting on pins 31 and 32.

The RF board has a 1/2 AA 3V battery (SANYO CR14250SE) to provide memory backup for the ETOL IC during those times that the unit is disconnected from vehichle power.

9.1 Typical Voltages for Type-III Transponder:

The following table gives some typical values that can be expected in a working system. These values are not intended to reflect actual manufacturing test limits but are given instead to help the repair person diagnose a faulty tag.

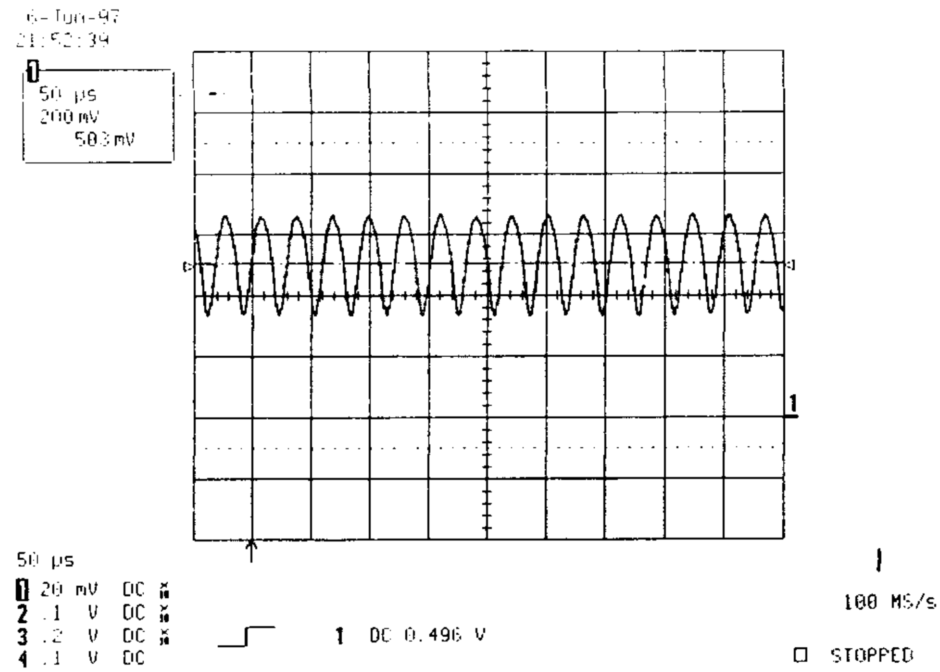
FUNCTIONAL BLOCK	LOCATION	NAME/FUNCTION	CHARACTERISTICS (approximate)
RF Board	**The characteristics listed here are in addition to those listed for the standard Type-II tag**		
	J2-P10 or U3-P25	Tag +3V supply	3.2 - 3.3V when inactive 3.0V when active
	J2-P12 or U4-P6	SW_5V	+5V when ignition is on 0V when ignition is off
	U3-P20	CS*	0V when active 5V when inactive This signal is driven by the micro but is buffered by transistor Q9 on the RF board
	J2-P5	CS	5V when active 0V when inactive This signal is driven by the micro
	J2-P3	INT*	0V when active 5V when inactive INT* is generated by the ETOL IC

			but is isolated by Q10 and Q11
	U3-P18	INT*	0V when active 3V when inactive INT is generated by the ETOL IC
	J2-P4 or U3-P19	HSCLK	5Vpp rectangular waveform when active, normally high, generated by the micro.
	J2-P6 or U3-P21	HTXDATA	5Vpp digital waveform, normally low, driven by the micro
	J2-P2 or U3-P17	HRXDATA	3Vpp digital waveform, driven by the ETOL IC.
	U3-P15	VBATMEM	3.2V when no vehicle power applied 2.3 to 2.7 otherwise
Digital Board			
	J2-P10 or Q5 emitter	Tag +3V supply	3.2 - 3.3V when inactive 3.0V when active
	J2-P12 or Q7C	SW_5V	+5V when ignition is on 0V when ignition is off
	J2-P5 or Q8C	CS	5V when active 0V when inactive This signal is driven by the micro
	Q8B or U3-P55	CS*	0V when active 5V when inactive This signal is driven by the micro
	J2-P3 or U3-P51	INT*	0V when active 3V when inactive INT is generated by the ETOL IC but buffered by Q10 and Q11 on the RF board.
	J2-P4 or U3-P47	HSCLK	5Vpp rectangular waveform when active, normally high, generated by the micro.
	J2-P6 or U3-P48	HTXDATA	5Vpp digital waveform, driven by micro, normally low
	J2-P2 or U3-P49	HRXDATA	3Vpp digital waveform, driven by the ETOL IC, normally low.
Digital Board serial port IC	U1-P1		7.25V average with 5Vpp 20KHz square wave riding on top
	U1-P2		10VDC
	U1-P3		2.5V average with 5Vpp square wave riding on top
	U1-P4, -P5, -P6, -P8, -P13, -P14, -P15		0V
	U1-P7		-10V
	U1-P9, -P10, -P11, -P12	serial port signals to/from micro	5V
	U1-P16	5V power pin for IC	5.0V

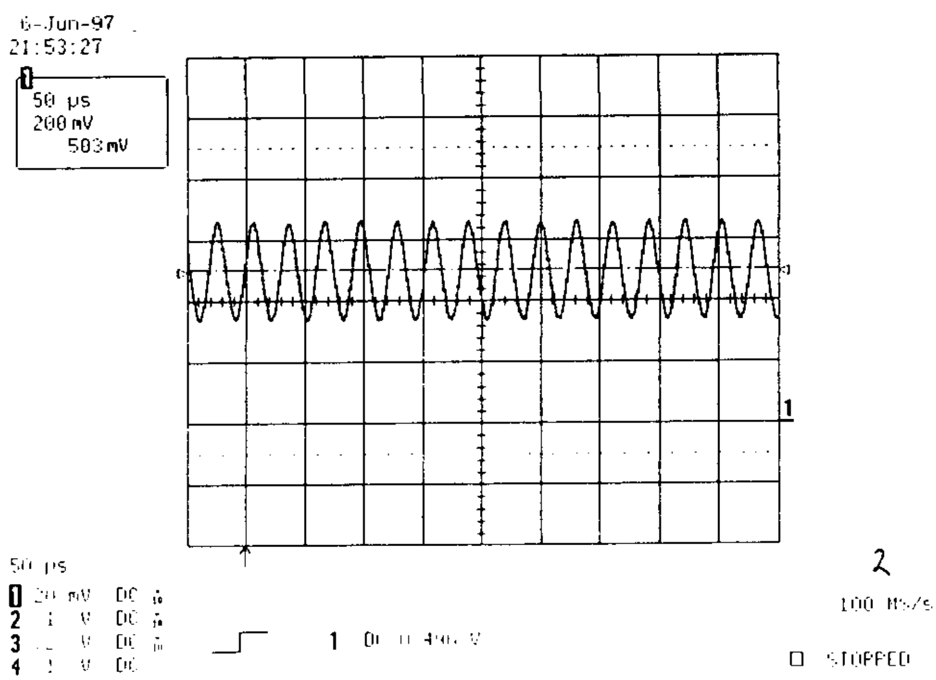
Digital Board 5V regulator	U4-P1, -P2	regulator output	5.0V
	U4-P3, -P4	ground	0V
	U4-P5	low voltage detect	5V
	U4-P6, -P7	voltage adjustment pins	1.28V
Digital Board Micro. resonator	U3-P31	micro's input pin from resonator	2.2VDC level with 2.6Vpp sine wave riding on top
	U3-P32	micro's output pin to drive resonator	2.3VDC level with 3.7Vpp sine wave riding on top
Digital Board Driver Interface	U3-P4	Red LED drive pin	5V when active, otherwise 0V
	Q3B	Q3 base signal	3.4V when active, otherwise 0V
	Q3E	Q3 emitter	2.8V when active, otherwise 0V
	CR3 anode	Red LED anode	1.7V when active, otherwise 0V
	U3-P2	Yellow LED drive pin	5V when active, otherwise 0V
	Q2B	Q2 base signal	3.4V when active, otherwise 0V
	Q2E	Q2 emitter	2.8V when active, otherwise 0V
	CR2 anode	Yellow LED anode	2.0V when active, otherwise 0V
	U3-P3	Green LED drive pin	5V when active, otherwise 0V
	Q1B	Q1 base signal	3.4V when active,otherwise 0V
	Q1E	Q1 emitter	2.8V when active, otherwise 0V
	CR1 anode	Green LED anode	2.0V when active, otherwise 0V
	U3-P45	Beeper drive signal	5Vpp, 4KHz square wave

10.0 Typical Oscilloscope and Spectrum Analyzer Waveforms for Various Circuit Blocks

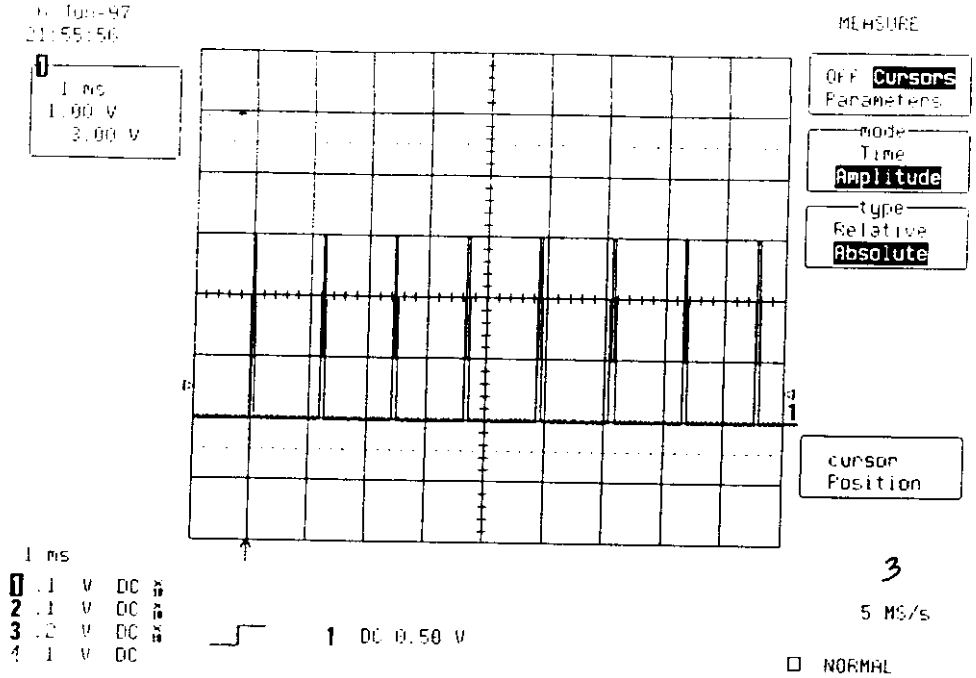
On the following pages are several waveforms that will aid the technician in debugging the tags and clarify the text. The waveforms are described with a brief caption and are listed in the table of contents. Following these oscilloscope traces are spectrum analyzer plots showing some of the RF characteristics.



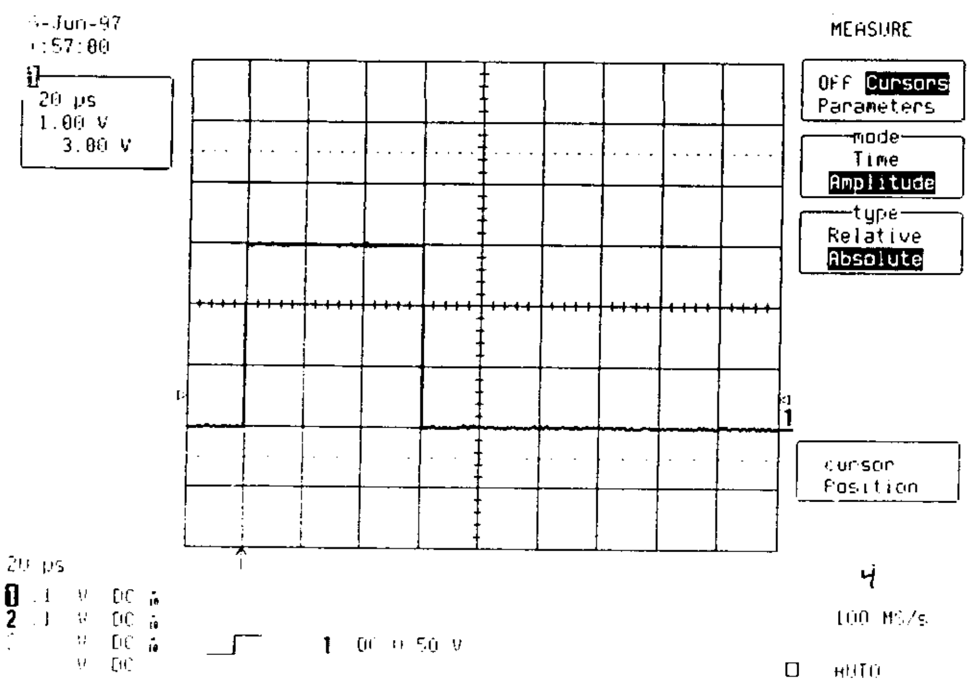
10.1 Fig 3. ETOL IC Pin 7, 32KHz Crystal Driver Waveform.



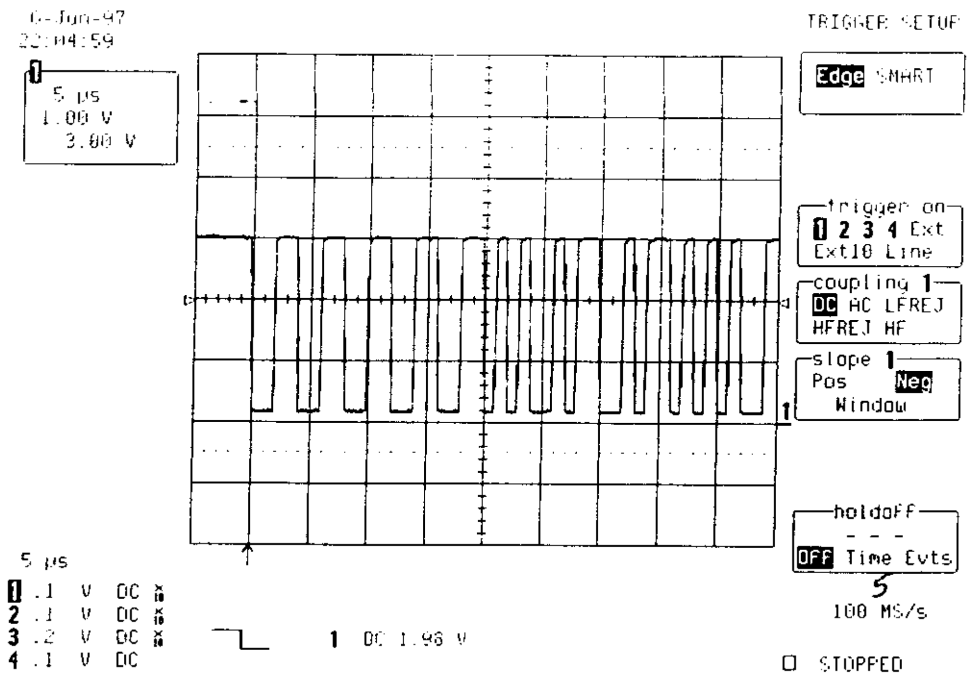
10.2 Fig 4. ETOL IC Pin 8, 32KHz Crystal Output Waveform



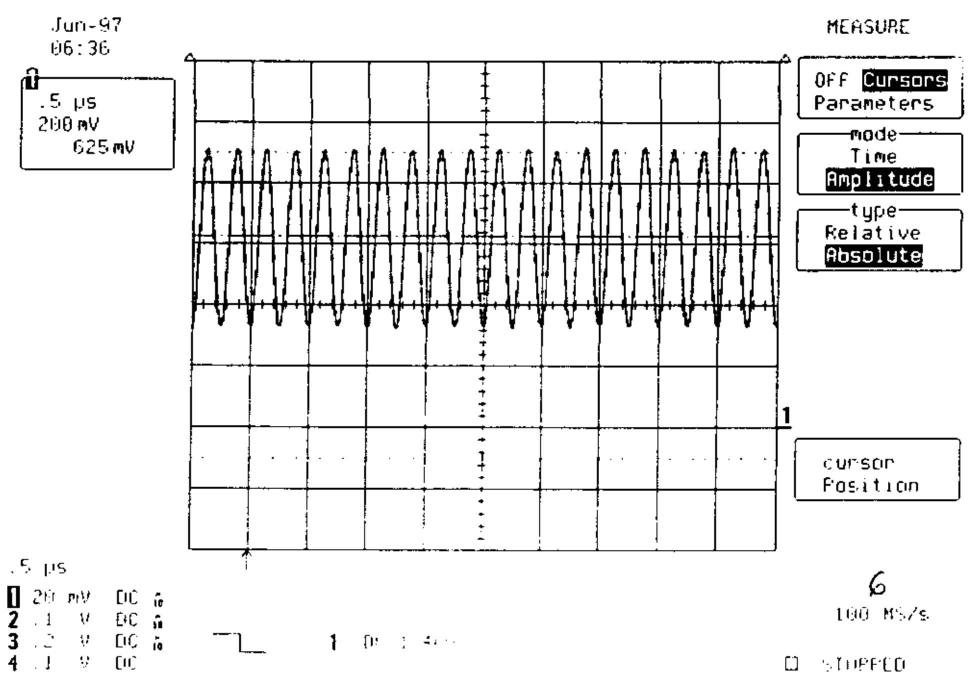
10.3 Fig 5. ETOL IC Pin 14, Detector Diode Bias Waveform During "Sniff Mode"



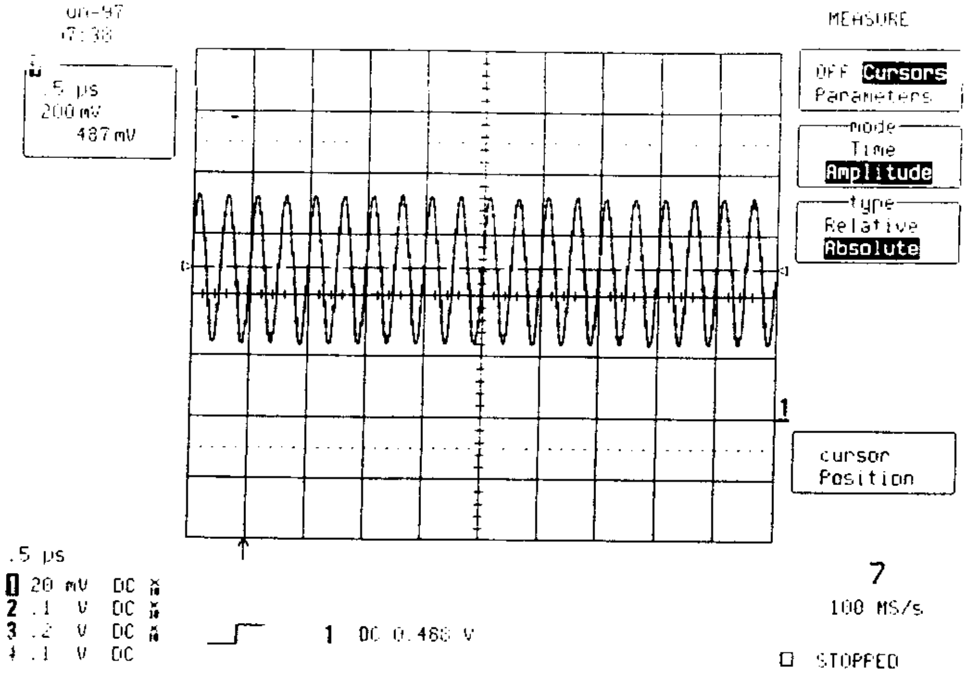
10.4 Fig 6. ETOL IC Pin 14, Detector Diode Bias Waveform During "Sniff Mode", Zoomed In



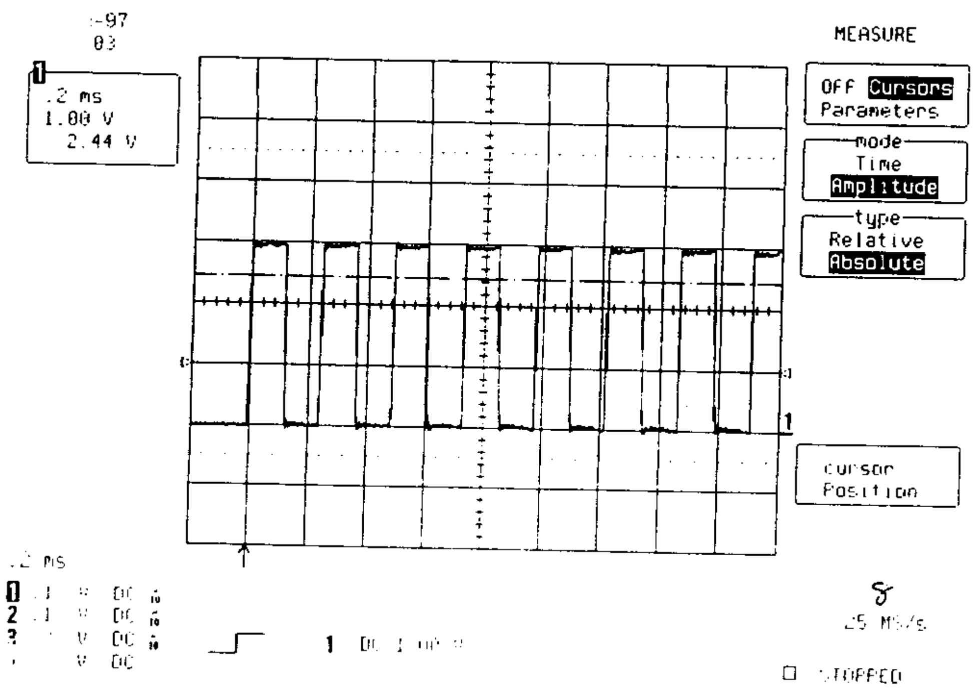
10.5 Fig 7. ETOL IC Pin 1, BBDATAOUT Waveform



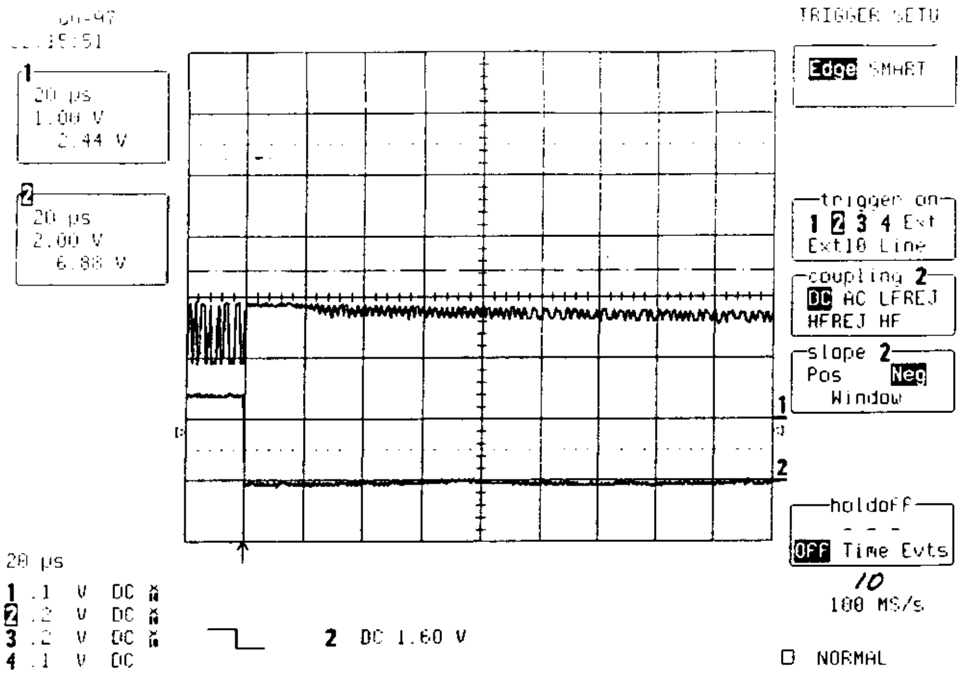
10.6 Fig 8. ETOL IC Pin 3, 4MHz Crystal Driver Waveform



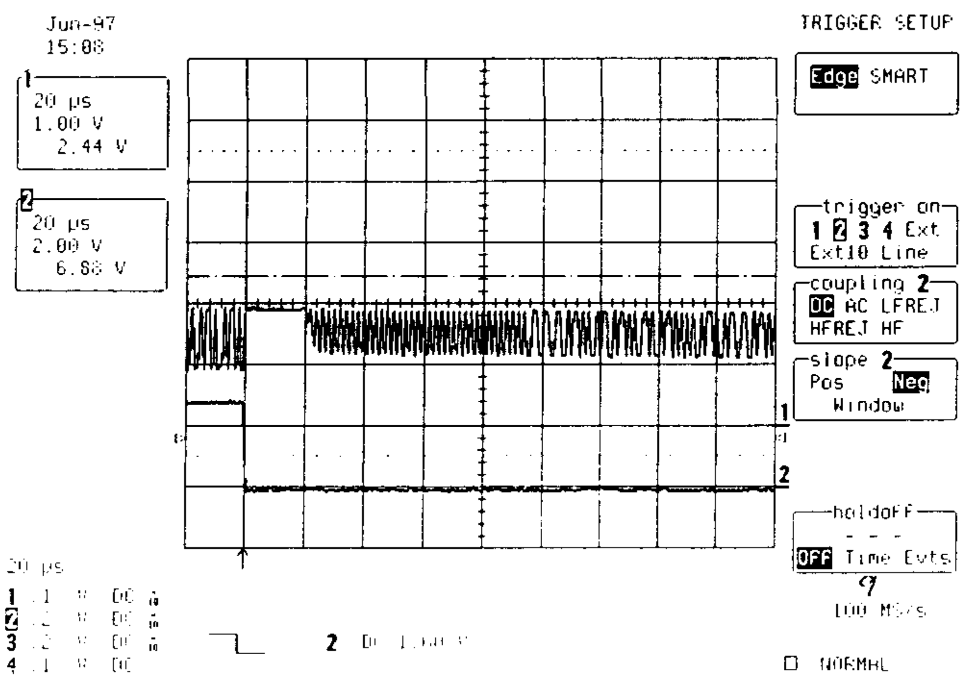
10.7 Fig 9. ETOL IC Pin 4, 4MHz Crystal Output Waveform



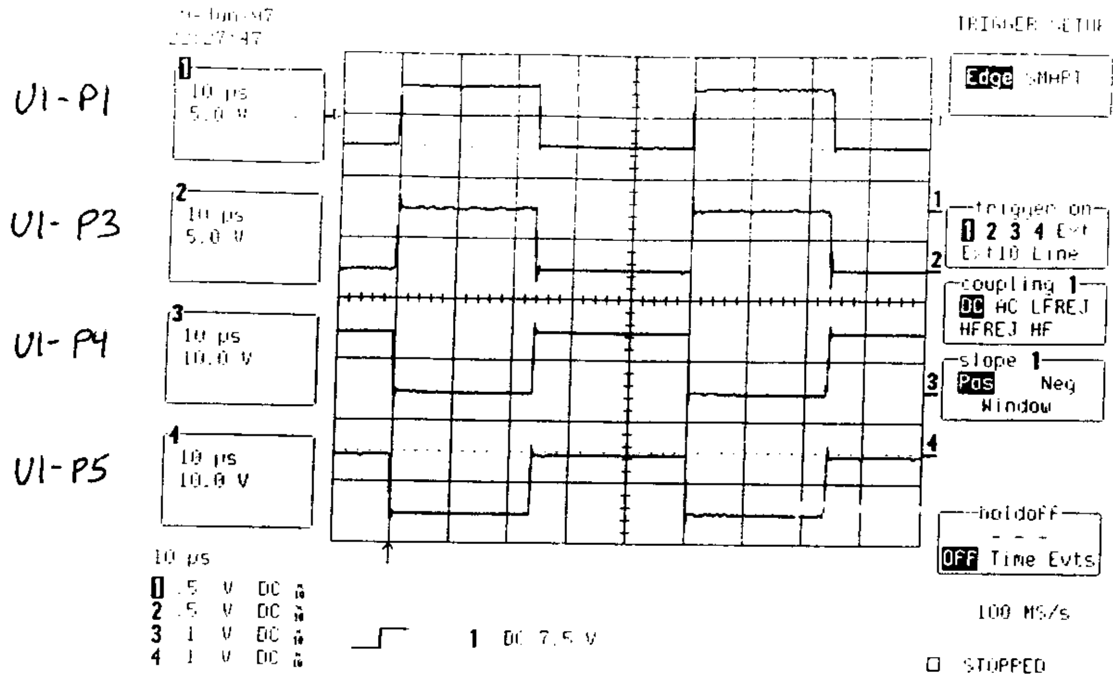
10.8 Fig 10. ETOL IC Pin 22, Beeper Drive Waveform



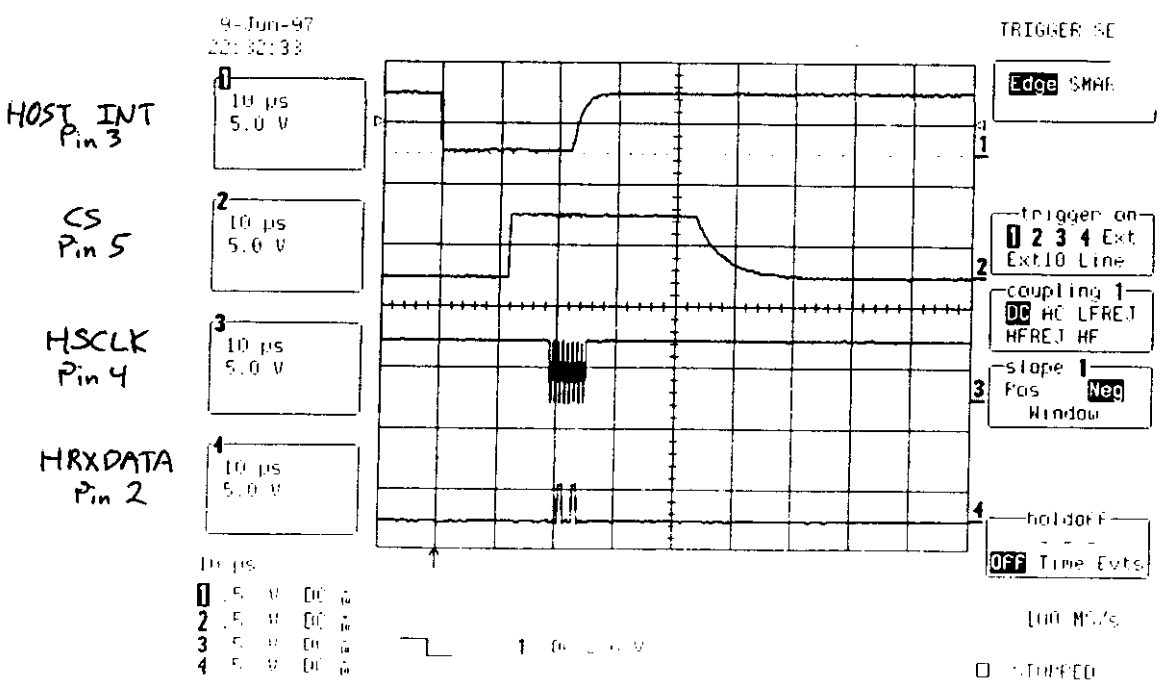
10.9 Fig 11. ETOL IC Pin 10, BBDATAIN Waveform with Weak Signal



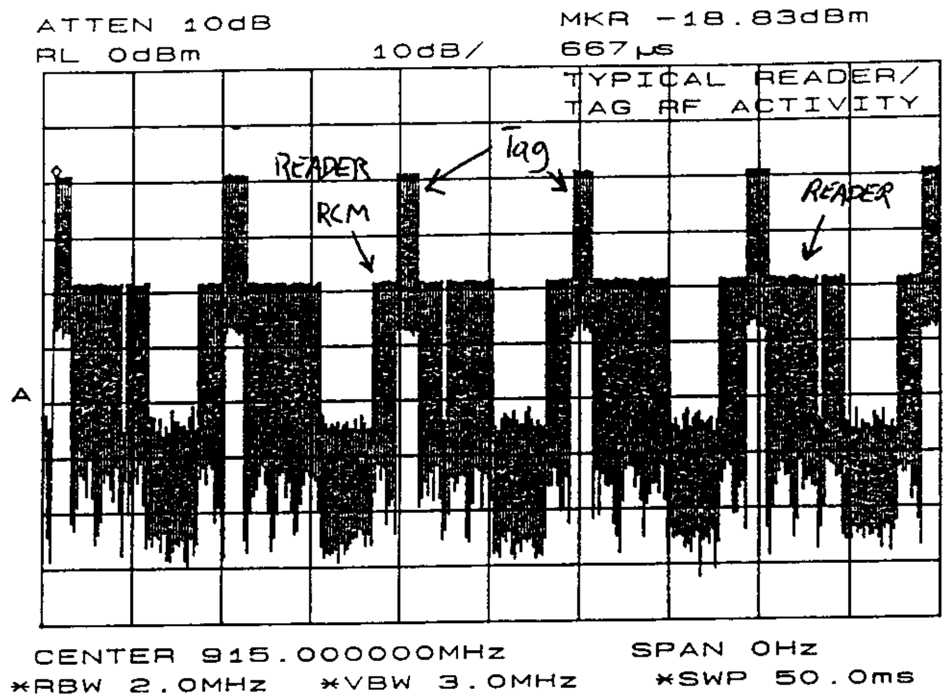
10.10 Fig 12. ETOL IC Pin 10, BBDATAIN Waveform with Strong Signal



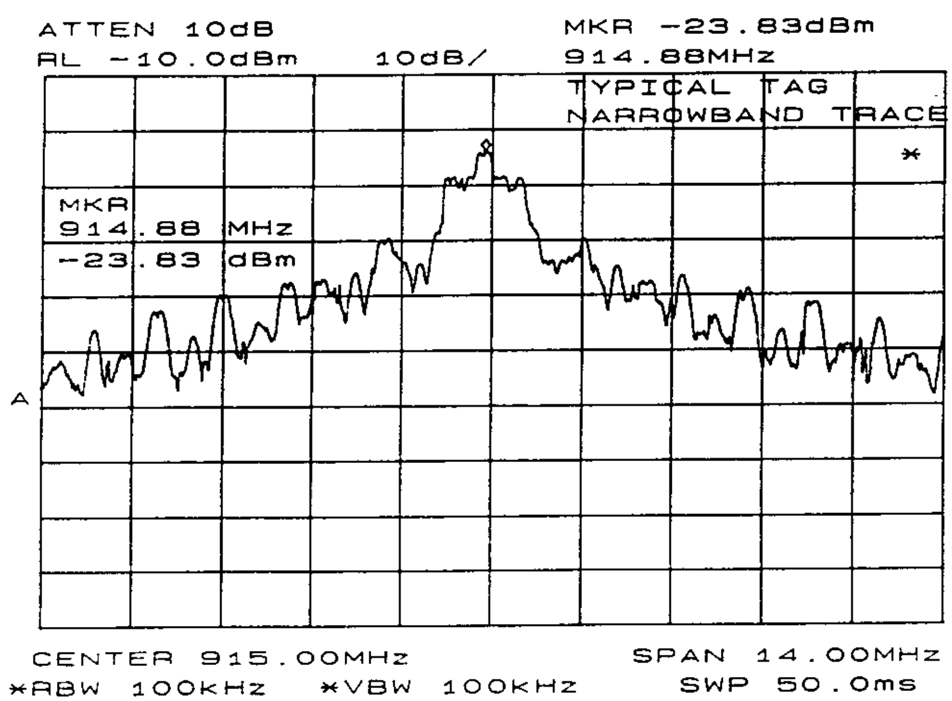
10.11 Fig 13. Digital Board Serial Port Interface Chip (U1) Waveforms



10.12 Fig. 14. Serial Interface Signals on Type-III Brd-to-Brd Connector



10.13 Fig 15. Spectrum Analyzer Plot Showing Typical Reader and Tag in Link Report Mode



10.14 Fig 16. Spectrum Analyzer Plot Showing Typical Tag Modulated RF Output file: etoltec.doc