Theory of Operation

TITLE: 100G ERT Theory of Operations (Phase 1 Direct and Remote, SCM-only)
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REVISION HISTORY

		Added Remote Interface	3.05/08		

1.0 PURPOSE

The purpose of this document is to describe the theory of operation for the 100G ERT® unit.

2.0 DEFINITIONS

ERT® Unit	= Encoded Receiver Transmitter
MCU	= Mobile Collector Unit – vehicle mounted reading device for the 100G unit.
FC200R	=Field Collector Unit – handheld reader / programming device for the 100G unit.
Rx	= Receive
SCM	= Standard Consumption Message
Tx	= Transmit
µP	= Micro Processor

3.0 CIRCUIT DESCRIPTION

3.1 General

The 100G is a new generation of Gas endpoints including receive capability and both high power and low power transmit capability. The unit operates in the 908 to 924 MHz band and is usable in handheld, mobile and fixed network applications. The heart of the 100G Radio section is the MICR505L RFIC, which integrates TX and RX as well as Synthesizer, Crystal Oscillator, OOK Modulator, and RFIC voltage regulator functions

3.2 Oscillator

The 16 MHZ reference frequency is provided by a shunt mode crystal working in conjunction with the MIC505L RFIC. The crystal is loaded by shunt capacitors C416 and C417 together with stray capacitance and Firmware selectable shunt capacitors within the MIC505. At initial test, the crystal output frequency is tuned to within 2 PPM. Adjustment is accomplished by measuring the RF frequency and minimizing RF frequency error by making appropriate adjustment to the reference frequency.

3.3 Transmitter

In handheld and mobile applications, the 100G operates primarily in OOK mode at +10 dBm (Low power) provided by the RFIC. Requested special messages use high power mode, described below.

In Fixed network applications the OOK output is +24 dBm (high power) provided by Q304, a single RF transistor amplifier stage driven by +10 dBm from the RFIC. Q301 and Q302 sense the Q304 collector current as a voltage drop across R302 and R303 in parallel, and adjust Q304 base to hold current constant. Low current is extremely important to allow battery life of 20 years or longer, so switch Q 303 enables the Bias control section only when the transmitted bit is a one.. By disabling PA on zero bits when no RF is desired, battery power is conserved. Operating Voltage for the high power stage is a regulated 3V, enabled for the duration of high power TX events.

3.4 Transmit Frequency Control

Transmit frequency is controlled by the transceiver synthesizer which is programmed by the microcontroller and writes to its registers via the SPI connection.

3.5 RF Switches

U201and U202 are RF switches used to connect either the High power transmitter path or the receiver and low power transmitter path to the low pass filter, antenna match and antenna.. With U301 pin 6 high and pin 4 low and U302 Pin 4 low and pin 6 high (verify) the RF path between antenna and RFIC is selected. When the polarity of the pins on U201 and U202 is reversed, the high power RF amplifier is connected between RFIC and antenna

R318, R319, R324 and R325 are decoupling resistors. R201, R202, R203 and R204 are reference resistors for the µP. C202, C204, and C207, C346 and are bypass capacitors.

3.6 Low Pass Filter

L201, L202, C206, C208, and C209 form a 5 pole filter designed for minimal effect at the TX frequency and maximum attenuation of harmonics. The filter is directly in the path to the antenna, and is not affected by the selection of high power or low power modes.

3.7 Antenna

Depending on antenna switch control voltages the antenna connects to either the Power amplifier output or the RFIC antenna pin. The antenna is a Patch integrated on the Printed Circuit board. C8, C9, and L2 match the antenna impedance to the 50 ohm lines to either RFIC of RFPA. The antenna is tuned to operate properly when loaded by potting and the dielectric of the polycarbonate housing.

3.8 Data Transmit

Data messages, called Standard Consumption Messages (SCM), are 5,8 mS length Manchester-encoded and contain the unit ID number, meter reading and other information. The data is transmitted using Manchester encoded on/off keying (OOK) of the transceiver output and the external power amplifier. For each transmission, frequency use is determined by one of 256 pseudo random patterns, each of which uses all 50 channels, with each channel used equally on average. The pseudo random pattern used is determined by the last 4 bits of the unit serial number. Collisions will occur when two or more endpoints transmit at the same time and on the same frequency. Use of many different Pseudo random TX frequency patterns helps to assure, that the same endpoints to not cause repeated collisions in a short time period. Reading devices used with the system are not synchronized to the pseudo random transmit frequency pattern. Uplink responses to programming and interrogation messages are encoded and transmitted in the same fashion.

3.9 Data Receive

Downlink messages for programming and interrogation are received by the transceiver which provides NRZ data and clock signals to the microcontroller. The microcontroller interprets the downlink packet, performs the requested action, and generates the uplink response when appropriate.

3.10 Power Supply

The power supply consists of three main sections. Primary power to the 100G supply circuit is provided by a 3.68V lithium thionyl-chloride A-cell connected to J1. The battery has a nominal capacity of 3.6 Ah.

3.10.1 3V RF Power Supply voltage

All RF parts operate using voltage from the 3V regulator U1 which is turned on just prior to each RF activity and held in an off state between RF activities to conserve current.

3.10.2 RF IC regulator

The RFIC operates at 2.7 V voltage supplied by a regulator imbedded in the RF IC. This functionality resides in the chip but operates independent of the rest of the RF IC under control of the microprocessor.

3.10.3 Microprocessor supply

At 3.6 V supply, the µP sleep current drain exceeds the levels needed to allow 20 year operation on a single battery. In addition, the Micrel RFIC will not interface directly to the µP output voltages produced with 3.6 V operation. To supply the µP, Q1 and Q2 are connected as diodes, limiting µP voltage to about 2.7 V. At 2.7V, the µP IO is compatible with the RFIC and µP sleep current is reduced to about 2uA, supporting the required battery life. C7 holds sufficient charge to maintain µP voltages within required limits when the battery briefly sags during high power messages. In the Remote version of the 100G, C7 is increased from 20 uF to 47 uF to minimize microprocessor voltage sag during TX cycles.

3.11 Read Switch (Direct Mount 100G only)

The read switch S103 is magnetically coupled to the attached meter, and changes state as the meter register rotates. The main micro detects the switch state changes, de-bounces the switch and stores the count information.

3.12 Tilt and Tamper Switches

Switch S102, along with R104, provide tilt indication to the micro. When the switch is closed by tilting the assembly, it pulls pin 24 of the micro to ground. When the switch is open, pin 24 remains high. Switch S101, along with R103; provide magnetic tamper indication to the micro. When abnormal external magnets are applied in a tamper attempt, S101 closes, pulling pin 28 of the micro to ground. When the switch is open, pin 28 remains at the µP operating voltage ~2.7 volts. The 100G remote version does not have a magnetic tamper switch, but does have a dedicated cut cable tamper circuit described elsewhere. Cut Cable tamper is reported as Magnetic Tamper.

3.13 Remote interface

Count sense circuits (White wire)

R109 provides a pull up path to the 3.6 V battery voltage through isolation resistor R110. Externally, any of several types of remotely located encoder devices can be connected. When the encoder device is closed during a count cycle, the voltage at R109 is briefly pulled low by count enable circuitry, causing the uP to see a state change and register a count. Q101 provides level shifting to the uP voltage levels.

3.14 Count Enable circuits (Red Wire)

Since a conbtinuous pull down would consume current any time the external decoder device is closed, count enable is pulsed. The pulse width is 30 uS to allow driving a cable oof 300 feet, and the count is sampled every $1/128^{th}$ of a second (roughly 7.8 mS). Q103 is driven by the uP to provide ground to count sense circuits when the external encoder is closed.

3.15 Cut sense tamper (Blue Wire)

The cut tamper wire is connected to the red count sense wire at the remote encoder, causing Q102 to be turned off. The Up sees a low input and no tamper is reported. If the blue wire or the entire wire bundle is cut, Q103 turns on and the uP reports a tamper.

3.16 Count firmware

There are two versions of count firmware in the 100G remote, one for pulser type encoders which feature brief (25 to 50 mS) encoder pulses. Pulser encoders are not debounced on the closed pulse widths. For donut and reed switch encoders, the standard 100G debounce method is used.

3.17 Test Points

The 100G ERT® Unit has test points that can be utilized by test hardware and test personnel to align, monitor and trouble shoot the ERT® Unit. Refer to schematic SCH-5000-001 to locate the test points.

3.18 Main Microcontroller

The main micro, U401, is a Texas Instruments MSP430F1232IPW. In current conservation mode the µP clock is supplied by Y401, a 32.768 KHz crystal. When faster execution is necessary, the µP runs on it's internal oscillator at up to 5 MHz Further, it receives an 8 MHz clock from the TCXO (TCXO divided by two) periodically to perform accurate functions such as transmitting, receiving and real time clock updates. There are several referencing resistors on the circuit board to assure that micro pins are not left in a high impedance floating state, whereby they can sink or source high current. These include R401-R403, R407-R418 and R422-R427. An in depth description of the micro's functionality is explained in the firmware section of this document. Below is a table of the micro's pins and their functions. ERT® UNIT SPECIFICATIONS

3.19 ERT® Unit Specifications

The specifications listed apply to the 100G ERT® Unit as measured on the FCC site. The unit should be installed in housing and potted.

Item #	Description	Specification
1	Transmit High Frequency	922 MHZ
2	Transmit Low Frequency	908 MHZ
3	Receive Frequency	908-922 MHZ[2]
4	Transmit BW	<200 kHz
5	Transmit Power	FN mode: +24 dBm EIRP Mobile mode: +10 dBm EIRP
6	Receive Sensitivity	-100 dBm
7	Idle Current	<2µAmps

4.0 TUNE AND TEST

4.1 Setting Frequency

During manufacturing, it is preferred to set the unit on frequency. Although the unit is synthesized, there are slight variations in the finish frequency of the crystal as well as variations of the amount of loading capacitance on the crystal. Even though these variations are slight, they can add up to several kilohertz of offset at the transmit frequency. There is also a slight shift in frequency due to capacitive loading effects caused by potting. During manufacturing the frequency is calibrated before the unit is potted, with a frequency offset to accommodate the expected change when potted.