Automatic Meter Reading Products

Detailed Descriptions of the 40GN ERT® Module

ITRON INC.

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INTRODUCTION

Our newest ERT module, the 40GN ERT Unit, represents a significant change from the circuitry incorporated in our previous gas and electric utility meter reading modules. The electronics have been upgraded in order to comply with the new FCC emission limits and to address the needs of the water utility market.

The 40GN ERT module employs a microcontroller and a custom integrated circuit to allow communications between a consumptive utility meter and a mobile or handheld meter reader device. The software-based architecture within an ERT module utilizes on-board firmware, which allows each unit to be customized for easy installation, field service and interfacing with the billing systems of virtually all utilities. The customer, via this programming link, **cannot** alter transmitter power and RF timing. Once the wake-up tone, which is unique for each utility, is set and the ERT module is electronically locked, the customer cannot reprogram any characteristics of the device. RF characteristics of the device are not programmable. Only items such as initial meter reading settings, type and characteristics of the utility meter on which the unit is installed and tamper sensor resets are programmable by the customer. None of these programmable features affect the RF characteristics of the ERT module.

All circuitry resides on a single ceramic substrate (circuit board). The encoder magnet is located in an adjacent shaft which essentially performs the same encoding technique as utilized in the original 40G ERT Unit (FCC ID # EWQ90F2482517-A). Much of the logic circuitry has been integrated into a custom integrated circuit. This breaks the ERT Unit hardware into two sections, logic and RF, described in the following sections.

DATA MESSAGE TRANSMISSION TIMING

When awakened by a coded message from a ReadOne® Pro Unit, DataCommand® Unit or DCH-PN Unit, ERT modules transmit a burst of 8 utility usage messages during a 656 msec. period and repeats the bursts every 11 seconds. Individual messages in the 8-message bursts are just under 6 msec. wide, with a separation of about 88 msec. The quiet time between the 8-message bursts is about 10.3 seconds.

ERT UNIT RF SECTION DESCRIPTION

Both the receiver and transmitter sections of a 40GN ERT module share the same basic oscillator circuit. The receive frequency is tuned to 955 MHz and the transmit frequency range is 910 to 920 MHz. The normal state of an ERT module at rest is "Receive Mode". When in "Receive Mode", the ERT module continuously monitors for the presence of a coded command to transmit the current meter reading. The receiver is always sampling except when commanded to transmit consumptive utility data.

The command to transmit data is a coded amplitude modulated (AM) signal in the range of 952 to 960 MHz that is received from a mobile or handheld device. When this signal is detected, the ERT module switches to the Transmit Mode then transmits a data message eight (8) times. The transmit frequency of each of the eight (8) messages is randomly selected within the ERT module from among the 31 frequencies available between 910 and 920 MHz. This method of operation improves the ability of the mobile or handheld data collection device to successfully read the consumptive utility usage data because the chance of two or more ERT modules transmitting at the same time and at the same frequency is significantly reduced.

OSCILLATOR (Q1)

The design is based on a Colpitts Oscillator (refer to Figure 1) consisting of Q1, C2, C3, C4, C5, C11, C12, C15, CR2, and a tuning stub and microstrip antenna which is connected to the collector of Q1. Capacitors C4 and C5 control the positive feedback which is necessary to sustain oscillation. The microstrip antenna provides tank circuit inductance to resonate with the capacitances C3 and C11 to provide a coarse frequency adjustment by capacitively loading the microstrip. The tuning stub offers a means of fine tuning the oscillator receive frequency. CR3 is a PIN diode which enables C12, CR2, and C15 to shift the ERT Unit frequency into the transmit band. C12 (a laser trimmable capacitor) provides the fine-tuning of the ERT into the transmit band.

Q1 is a PNP transistor. By using this bipolar technology, the driving logic that is tuned in the previous version 40G can be used without modification. Also, this choice enables the antenna to be at ground potential nearly all of the time. (The implications into migration can be easily recognized.)

R2, R3, R4, R5, and CR1 provide a temperature compensated bias current into Q1 for both receive and transmit operation. C2 is a 900 MHz bypass for the base. C1 contours the current ramping of Q1 for receive operation, while C6 effectively disables this ramp action to occur in transmit mode. R4 and C6 control the transmit power of the unit.

RECEIVER ENABLE/DISABLE

In receive mode, the oscillator is switched on and off by the logic of U51. When pin 17 goes low, a ground return is provided through R2 for a base voltage ramp to begin. R5 turns this changing base voltage into an increasing current through Q1. When pin 17 goes high, Q1 is disabled. R2, R3, R5, C1 and CR1control the characteristics of the ramping current.

TRANSMIT/RECEIVE CONTROL

The tank circuit is changed to allow the frequency to shift from the receive band to the transmit band at 910 - 920 MHz. This frequency change is controlled by the opposite logic of pin 19 of U51 and pin 18 of U52. Acting differentially on CR3, these pins negatively bias CR3 with full supply voltage in receive, or forward bias CR3 through R8 in transmit. The forward biasing of CR3 enables C12, CR2, C15, and LI, thus lowering the oscillation frequency of Q1 into the transmit band.

TRANSMIT FREQUENCY CONTROL

The transmit frequency is varied within 910 to 920 MHz by the DC voltage on pin 22 of U51. This voltage can be changed in 31 steps from approximately 0 to about 1.6 volts. The voltage on pin 22 is applied to one side of varactor diode CR2. Note: The upper voltage value on the anode of CR2 is determined by voltage division between R11 and the output impedance of pin 22 of U51. This output impedance has a part to part distribution of values. The voltage swing on the varactor, and consequently, the distribution of transmit frequencies will reflect that source of variability. Higher voltages on the anode of the varactor results in a lower frequency in the transmit band.

TRANSMIT DATA

Data messages are Manchester-encoded and contain the unit ID number, gas meter reading, and other information. The data is transmitted using on and off keying of oscillator Q1. The transmit data output is pin 16 of U51. When this output goes low, oscillator Q1 is enabled by establishing a base voltage through the base circuit components. When pin 16 goes high, the oscillator is disabled. Therefore, a logic 0 output on pin 16 represents presence of carrier, and a logic 1 represents the nonexistence of carrier.

RECEIVE AUDIO DETECTION

In the receive mode this circuit functions as a super regenerative detector. The principal of detection is to mark the time that it takes the oscillator to start up. Within-band RF energy present on the antenna, this energy will promote the starting up of the ERT Unit oscillator. This will cause the oscillator to turn on at a lower current level. Since throughout the RX enable time frame the current through Q1 is ever increasing, starting up at a lower current level equates to starting up sooner. The time to oscillator startup is monitored by the electronics in U51. If this timing varies at a rate equal to the programmed wakeup tone, the ERT will go into its transmit routine.

LOGIC DESCRIPTION

The RF section shown in block diagram in Figure 2, is controlled by the custom IC, U51. This device is designed specifically for the ERT Unit. It includes EEPROM memory for the ID number, RAM for storing programmed parameters, tone demodulator circuitry, three logic level output ports, latches for count and theft inputs, the master oscillator running at 32.768 kHz and a Digital to Analog converter to provide the tuning voltage for the RF transmit frequency.

U51 is controlled via a "micro-wire" interface by the microprocessor, U52, which is a masked device containing the 40GN software. In turn, however, U51 controls the clock of U52, which is cycled at one of two rates depending on the activity to be performed. The interface bus is used by U52 to communicate control instructions to and status register information from U51. Several other status lines on U51 are controlled or read by U52.

Inputs or count, tilt and magnetic theft detectors are fed simultaneously to both U51 and U52. These normally low inputs are sampled under software control to reduce the current drain in the event that a switch remain closed to battery voltage for extended time.

Referring again to Figure 1, the CKI clock input, pin 5, U52, is held low, causing U52 to be inactive, until U51 detects input or a valid wake-up tone. An active input condition causes U51 to assert the CKI clock line at 32.768 kHz. Once active, U52 becomes the system master controlled by the clock provided by U51. Besides detecting input conditions, U51 functions as the RF interface. Data demodulated from the receiver enters U51 at pin 12, is output from RX_DATA_OUT on pin 11 of U51, and finally is presented as a digital signal at pin 11 of U52. Information to be transmitted is sent from U52 to U51 via the micro-wire interface.

SOFTWARE

The controlling program, written in "C", is resident in U52 when it is manufactured. Refer to the flow chart in Figure 3. The program consists of three Modes:

I) Test Mode, for initial tune up,
2) Program mode, for setting options and,
3) Active Meter mode, usual ERT Unit operation.

The software has seven major routines that perform the ERT Unit functions:

1) Cold Start Initialization
2) Reset,
3) Deboz (debounce),
4) Sleep,
5) Transmit,
6) Receive Delay and
7) Process Commands.

An overall flow sequence between the custom, U51, and the controller, U52, can be described for the normal operation of the ERT Unit. The terms "SLEEP" and "HALT" are used interchangeably in the following discussion and indicate the period when the microprocessor is not active. Fast Start refers to the transmit/receive data mode, TRANSMIT, which requires a faster than normal CKI clock input. The general sequence for U52/U51 interaction is:

0. U52 clock line stopped, U51 inputs inactive.
1. U51 detects an active input or wake-up tone.
2. U51 turns on U52 clock and asserts Reset.
3. U52 starts at PC= #00, determines start mode.
4. U52 reads U51 status.
5. U52 executes appropriate process.
6. U52 tells U51 to shut off the clock.
7. U51 stops clock.
8. U51 waits for active input.

Governing priorities for the sequences above are:

1. Record Consumption Data.
2. Detect Wake-up Tone and Transmit Standard Message.
3. Record Tamper Detection.
   A. Magnetic
   B. Cable*
   C. Displacement*
   D. Tilt
4. Receive and process ReadOne® PRO Unit Commands

*Not Currently Implemented

COLD-START

This is the power-up reset routine. The first time battery power is applied, the custom IC control blocks and controller RAM space is loaded with default values. A copy of the last byte sent to each control block is also kept in RAM, (except for TXDAT, and EEPRM data). The Controller clock is placed in Fast Mode to facilitate a quick power-up sequence.

RESET

The custom IC chip will assert the Controller's reset line any time the µC CLOCK line changes state. Specifically, three conditions will result in a controller reset: Initial Power-up; Activation of any custom IC Status Flag during Sleep Mode; Change in µC Clock frequency. A general initialization of ports and registers must occur after any reset. Three RAM bytes are tested for pre-initialization. Failure of any of these bytes to match results in a Cold Start. A one-byte checksum is performed over the consumption data and compared to the last stored value. Failure to match causes a jump to WCHDG. A fourth RAM byte test determines if a general warm start or a fast start is followed.

DEBOUNCE (DEBOZ)

DEBOZ is the debounce routine executed during any warm start, or called as a subroutine during Tx/Rx mode. A RAM flag indicates how DEBOZ has been entered. Two successive custom IC status reads are required to determine a valid input edge. The first read clears the custom IC status. If the status remains cleared until the second read, a valid edge is determined. The Tilt Tamper line must maintain a steady level for the programmed amount of time before its level is determined. This loop will continue until a wake-up tone causes a branch to TONAK, or until the custom IC status becomes inactive.

SLEEP

Send HALT command to custom IC. If the tilt debounce counter is active, control jumps back to DEBOZ. If custom IC status bits are still asserted, jump to Warm Start to process them.

TRANSMIT

TRANSMIT oversees the RF transmission of data messages. The controller clock speed has been increased to accommodate timing requirements. The speed change caused U52 to reset U51. After determining that the clock is fast, the RESET routine has branched control here. A 40 ms delay is provided to setup the circuits prior to sending data. The meter counts may be updated at this time to speed up slow clock functions.

RECEIVE MANCHESTER DELAY

This routine enables a 512 Hz interrupt and then enters a sit-and-spin loop. The loop does nothing more than repetitively poll DEBOZ to check for input activity. The 512 Hz interrupt routine attempts to decode manchester data emanating from custom IC pin 11 and store it into RXBUF, a 12 byte buffer. Loop exit occurs when the loop delay expires, or if a valid ERT Unit ID has been received. RXINT is responsible for setting the appropriate flag.

PROCESS RECEIVED COMMANDS

This is really a group of subroutines that do internal decoding and control functions based on information received. It is also where the majority of the arithmetic operations are done to incorporate the options programmed into the unit.

ACTIVE METER COUNT MODE

Assuming an Initialized ERT Unit is in Halted mode and the Custom IC Chip is actively sensing condition changes:

Custom IC Chip (U51):
- Active Input is detected.
- Associated Status register bit is set.
- Controller Reset line is asserted.
- U52 Controller clock enabled at 32.768 KHz.

Controller (U52):
- Program execution begins at PC = #00
- General registers, micro-wire initialized.
- RAM test reveals Warm Start condition.

Jump to DEBOZ routine to debounce inputs.
- Input pins sampled
- If Falling edge of Count input, JSR UPCNT
- If Tone_Det, JMP TONAK
- If Tilt enabled and active, start tilt timer
- If Mag. Tamper enabled and edge detected, JSR UPMAG
- Otherwise send HALT command to custom IC

Custom IC chip (U51):
- Stop controller's clock input.
- Continue sensing input and wake-up conditions.

READONE® PRO UNIT PROGRAMMING MODE

One task of the ERT® Unit is to read and respond to the commands of the ReadOne® PRO Unit programmer. The ERT Unit must receive its program variables from the ReadOne PRO Unit and output data when requested. Assuming an initialized ERT Unit is in halted mode, actively sensing conditions, the program steps are:

ReadOne PRO Unit:
- Transmits Wake-up tone.

Custom IC Chip (U51):
- Detects tone, asserts TONE_DET status Flag,
- Enables U52 Clock, 32.768 KHz, resets U52.

Controller (U52):
- Begins code execution at PC=#00
- Custom IC Status is read/Input flags are reset
- FAST-CLK-ENABLE sent to U51 to speed up clock

Custom IC Chip (U51):
- Increase U52 Clock frequency to 786.4 KHz
- Assert U52 Reset.

Controller (U52):
- Code execution begins at PC= #00
- Program branches to TRANSMIT routine
- Transmit Buffer loaded with Consumption Data
- LOOP 8 Times:
  - Randomly tune transmit frequency.
  - DEBOZ polls inputs, updates counters.
  - DELAY called to delay 50 ms.
  - DEBOZ polls inputs, updates counters.
  - DELAY called to delay 50 ms.
  - Control to 10 S RCVDLY receive/delay loop.

ReadOne®:
- Receives Standard Consumption Message
- Transmits Command message

Controller (U52):
- RCVDLY clears RXBUF and 512 Hz timer.

Delay Loop:
- DEBOZ samples inputs, updates counters.

During Delay Loop:
- RXINT interrupts delay loop 512 times/sec.
- RXDLY counter is decremented
- If RXDLY reaches zero, Time_ Expired flag set
- Custom IC RX_ DATA pin sampled
- Decoded bits shifted into RXBUF
- Test for Valid ERT Unit ID and sets flag
- If Time_ Expired, or Valid_ ID interrupts disabled.
- If no Valid_ID, jump to SLOW

RSPND code block called when Valid_ID detected.
- Received data copied into RXMSG buffer
- RXBUF data prepared for CRC, (strip ID,CRC)
- CRC calculates checksum of received message.
- Calculated CRC compared to Received CRC
  - If not equal, jump back to RXDLY for remainder of 10 seconds.
- RXBUF.CMD command field tested for range
  - The interrogation commands do not test for Utility ID.

Response transmitted to all commands except CMD7.
RCVDLY reentered after transmitting the response.
Continue receiving and responding to commands.
IF "End of program" is received
- delay 5 minutes, setting the LOCK and Wake-up Tone,
- Jump to SLOW to return clock to 32.768 KHz.

Custom IC Chip (U51):
- U52 Clock line is returned to 32.768 KHz
- U52 Reset line is asserted

Controller (U52):
- Program begins at PC= #00
- RESET reads Custom IC Input Status
- RESET reads Custom IC W.D., and TONE_DET status
- SLEEP called if no activity
- SLEEP finally sends HALT command to Custom IC

Custom IC Chip (U51):
- U52 Clock line is halted.
- Clock will not stop if a status bit is set.

ERT UNIT SOFTWARE TEST MODE

The software in the ERT Unit provides an input command that allows two test modes for initial frequency alignment and verification testing of the encoder. Test Mode is entered by sending CMD7, Test Mode, from the ReadOne® PRO Unit.

Test Mode Command, CMD7, provides two test modes:

Test 1. Transmit Low, Mid-band, and High Frequency. Then return to SLEEP.

Test 2. Shift ERT from Rx to Tx Mode while Count Switch is active. The time looping within test mode 2 = 0.3 S * [DURATION]. Where DURATION is a 8 bit field supplied within the CMD7 syntax.

Upon receiving the appropriate command from the ReadOne PRO Unit, the ERT Unit will follow these steps:

TEST MODE #1

```
- IF RXBuf Mode =#1
        THEN transmit 12 bytes of all '00'
                Once at Lowest frequency
                Once at Mid frequency
                Once at Highest frequency
jump SLEEP
```

TEST MODE #2

```
- IF RxBuf.test =#2 THEN
        [LoopCNT] <= RxBuf.Duration
                WHILE [LoopCNT] > 0
                IF (Meter count Reed switch = Active)
                        THEN (Program Custom IC for Tx Mode)
                        ELSE (Program Custom IC for Rx Mode)
                Decrement Counter
jmp TRANSMIT
```

Block Diagrams

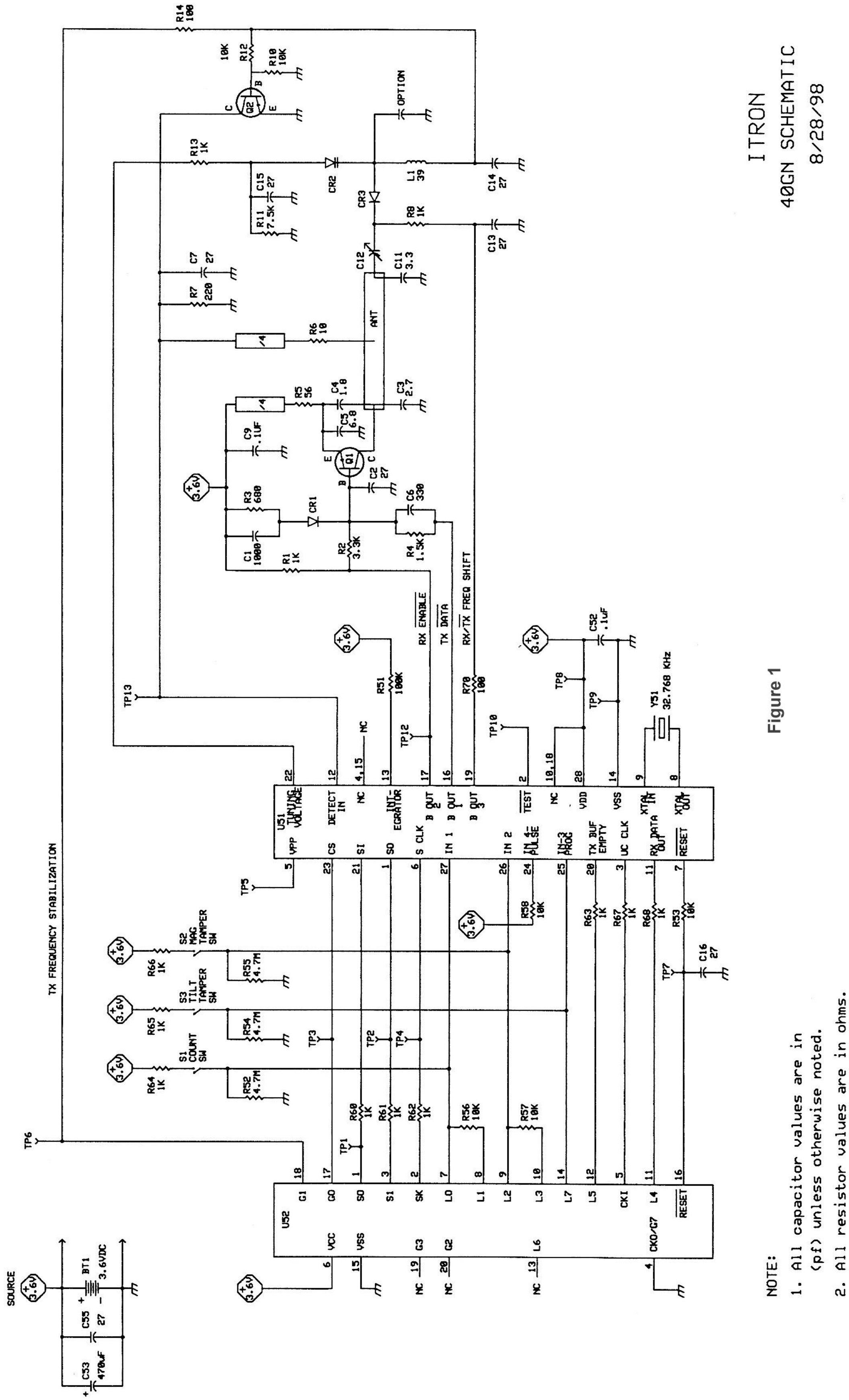
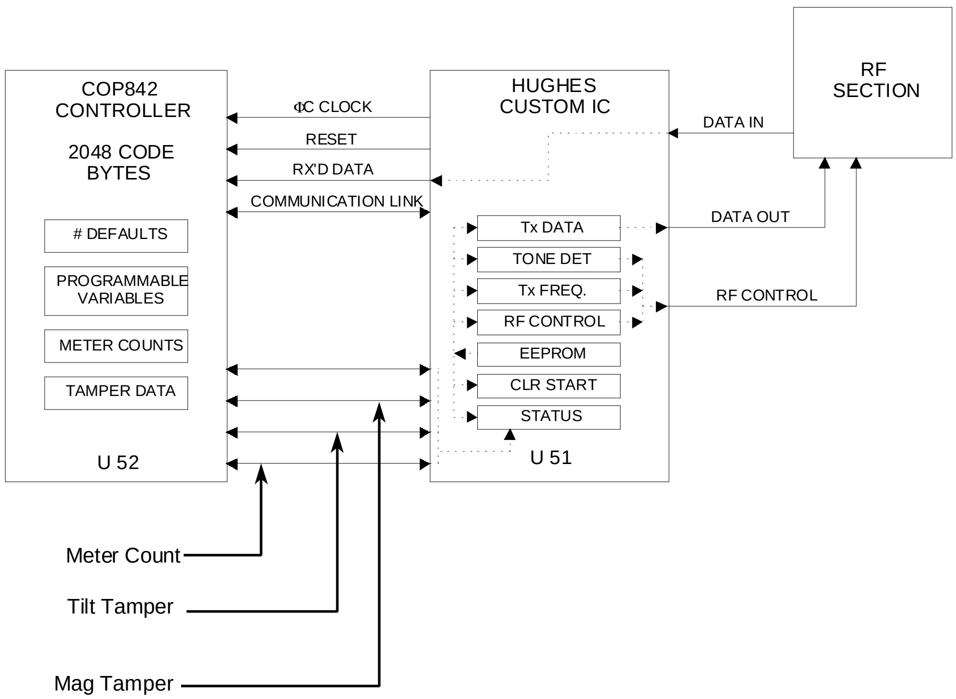
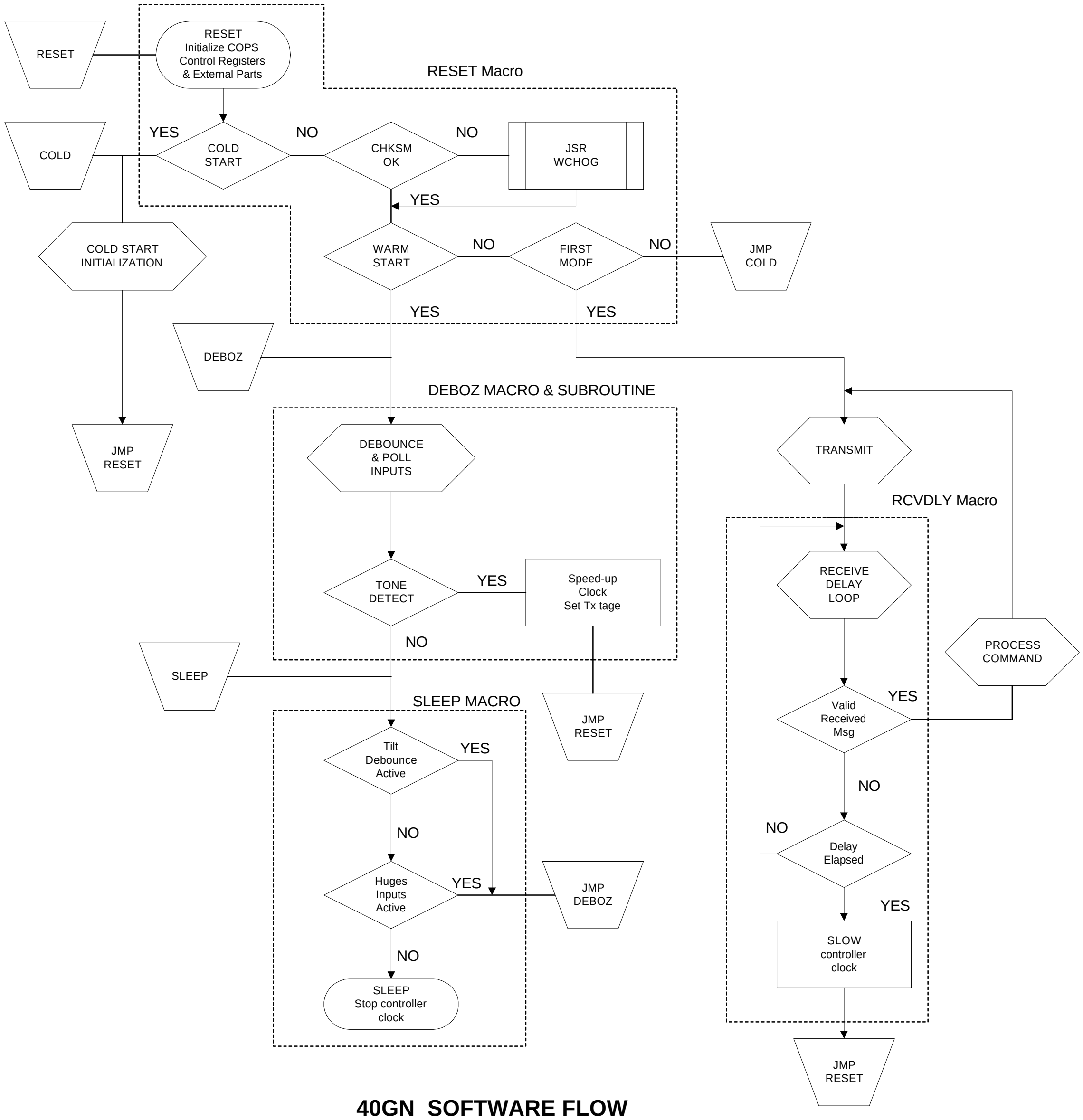


Figure 1



40GN Block Diagram

FIGURE 2



40GN SOFTWARE FLOW

FIGURE 3