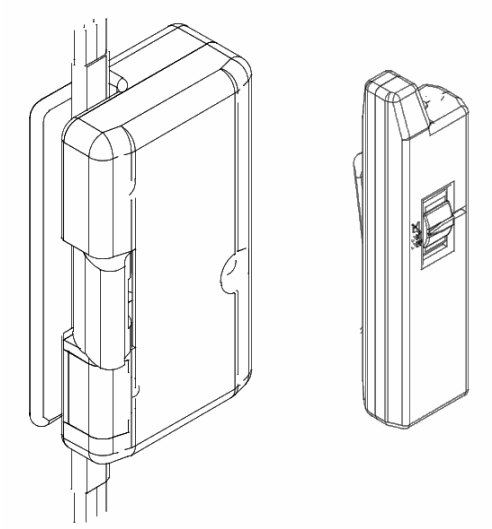

ENGINEERING DESIGN SPECIFICATION
RT30™
WIRELESS AC LINE POWER DETECTOR

Document No. EX-0031-380-A-1-B
4 January 2008
Bruce A. Wahler

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1.0 EXECUTIVE SUMMARY

1.1 OVERVIEW

The *RT30*™ is a medium-range wireless AC voltage detector system, designed to use either direct non-contact voltage (NCV) measurement of an AC line, using the built-in cable clamp or an external clamp probe; or to detect the light output of a lamp connected to the tested line through a light-detecting resistor (LDR), in cases where the wiring is inaccessible. Although the wireless operating range of the product is significant, power-saving methods are used both to improve battery life, and to allow the *RT30* to be used without the need for licensing as a radio transmitter. Provisions have been made for the addition of other sensors in the future, using the external probe input. The *RT30* is targeted towards residential and commercial electricians and building wiring installers.

1.2 MODEL COMPARISON

Feature	RT30-NA	RT30-EU
NCV Sensitivity	100-130VAC	200-260VAC
Transmission Frequency	914MHz	869MHz
Transmission Channels	3	3
External 120V NCV Probe	✓	
External 240V NCV Probe		✓

2.0 SCOPE

The scope of this document is to define the basic functions and system level specifications of the *RT30,* including some aspects of future expansion.

This specification is intended for use by members of the development team, and any development partners or consultants required by Extech. Outside development efforts and duplication of the product shall be covered by separate business agreements for development and duplication/manufacturing, as required.

Extech shall be responsible for maintaining and controlling document revisions for this specification.

2.1 DESIGN IMPLEMENTATION

This specification defines the high-level requirements of the product, including a detailed description of the user interface. The electrical design of the *RT30*, including the firmware shall be developed by Extech. The low-level design implementation of the mechanical parts shall be determined by Extech's PRC development partner, CEM.

Additional versions beyond the initial model may be required in the future. The basic design of the *RT30* shall allow for additional digital and analog probes to be attached, with minimal internal design changes; preferably, firmware-based.

3.0 SYSTEM ARCHITECTURE

The *RT30* system consists of three (3) parts: 1) a Transmitter Unit (TU) with integrated clip-on non-contact voltage (NCV) detector and light detector; 2) a wireless Receiver Unit (RU); and 3) an optional External Probe with integrated NCV detector.

3.1 FINDING A LIVE CIRCUIT BY VOLTAGE

The RT30 can be directly clamped on installed building wiring, as shown in Figure 1, and will detect the voltage applied to the wiring. When voltage is seen, the TU and RU will illuminate the Detect LEDs and enable the Detect Beeper when AC voltage is detected. When the voltage is removed (ex: by opening the circuit breaker), the Detect LEDs will go out and the Detect Beeper will be silenced.

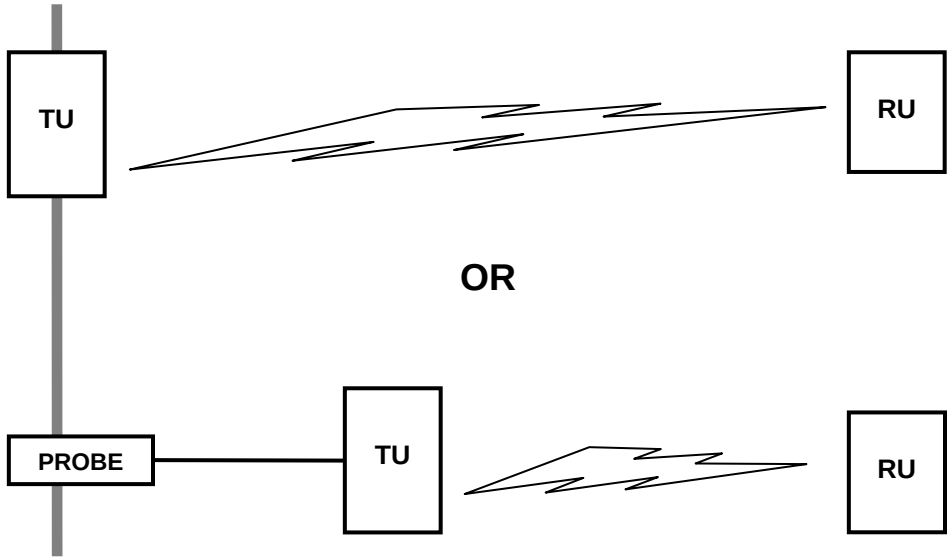

Figure 1 – Voltage Detection

3.2 FINDING A LIVE CIRCUIT BY LIGHTING

In situations where access to circuit wiring is limited, the RT30 can also detect if room lighting changes, as shown in Figure 2. The Light Meter can act as either a “light sensor” (the Detect LED lights when room lighting increases), or a “darkness sensor” (the Detect LED lights when room lighting decreases), depending on the calibration of the Light Sensor.

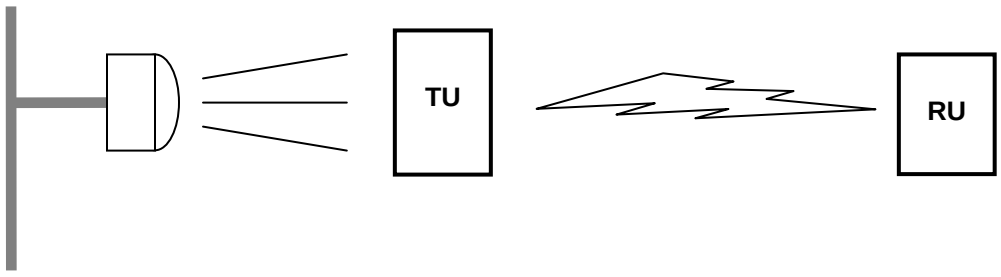

Figure 2 – Light Detection

4.0 SYSTEM SPECIFICATIONS

4.1 GENERAL SPECIFICATIONS

	Transmitter Unit	Receiver Unit
Display	Power, Detect, External Probe LEDs	Power, Detect, Communications LEDs
Controls	3-position slide switch	3-position slide switch
	Momentary switch for aux. functions	
Sample Rate	NCV: 2,000 samples/sec.	n/a
	LDR: 4 samples/sec.	
	External Probe: 2,000 samples/sec.	
Transmission Frequencies	EU Version: 868.4MHz, 869.0MHz, 869.6MHz NA Version: 913.4MHz, 914.0MHz, 914.6MHz	
Transmission Distance	~100m in an unobstructed field	
Transmission Power	+10dBm	n/a
Transmission Rate	4 updates/second	Immediate reception
NCV Detection (50-60Hz)	< 20mS	n/a
Light Detection	< 100mS	n/a
Alarm Status	Visual	Visual and audible
External Probe Port	Yes	No
Power Supply	Two (2) 'AAA' batteries	Two (2) 'AAA' batteries
Battery Life	3-4 weeks (4 hrs/day use), using alkaline batteries	1-2 week (4 hrs/day use), using alkaline batteries, Silent mode
Operating Temperature	14 to 122°F (-10 to 50°C)	
Storage Temperature	-14 to 140°F (-30 to 60°C)	
Operating Humidity	90%, 32-86°F (-10 to 30°C) 75%, 86-104°F (30 to 40°C) 45%, 104-122°F (40 to 50°C)	
Storage Humidity	90%	
Dimensions	TBD	TBD
Weight	TBD	TBD

4.2 BASIC OVERVIEW

4.2.1 Transmitter Unit

The Transmitter Unit is shown in Figure 3. Transmitter Unit features include:

- a Power/Mode switch to control the basic operation of the *RT30* TU;
- a Calibrate/Channel Switch to calibrate the Light Mode, and to change the wireless channel of the RT30;
- Power and Detect LEDs;
- an NCV Channel to route building wiring to the AC voltage detector;
- a Light Detector to measure room lighting;
- an External Probe Connector to attach auxiliary probes.

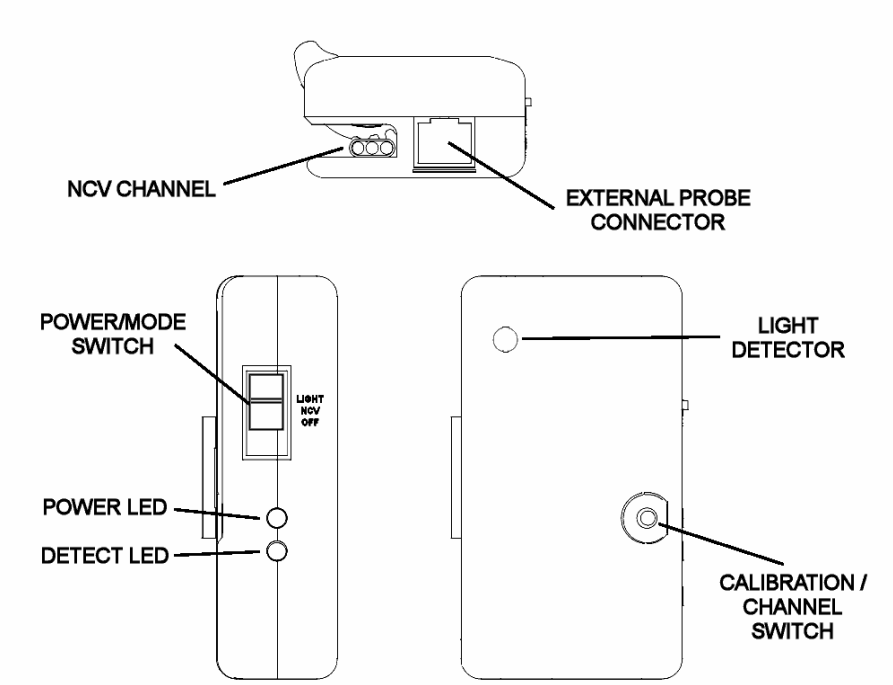

Figure 3 – Transmitter Unit

4.2.2 Receiver Unit

The Receiver Unit is shown in Figure 4, and has the following features:

- a Power/Mode Switch to control the basic operation of the *RT30* RU;
- Power, Detect, and Communication LEDs;
- a Detect Beeper for audible alarms and feedback, which can be silenced.

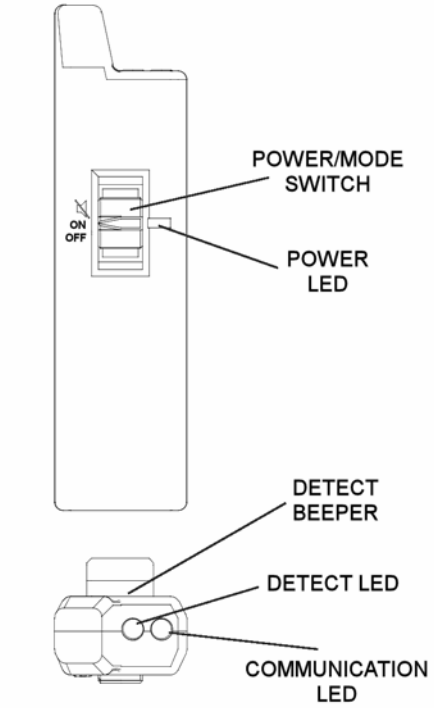

Figure 4 – Receiver Unit

4.2.3 External Probe

An optional External Probe can be used to clamp onto tested wiring. The probe is shown in Figure 5. Using the External Probe is exactly like using the NCV Channel. When the External Probe is plugged in, the External Probe LED shall indicate its use.

Note: Use of the External Probe overrides the setting of the Power/Mode Switch. Light Mode cannot be used while the External Probe is attached.

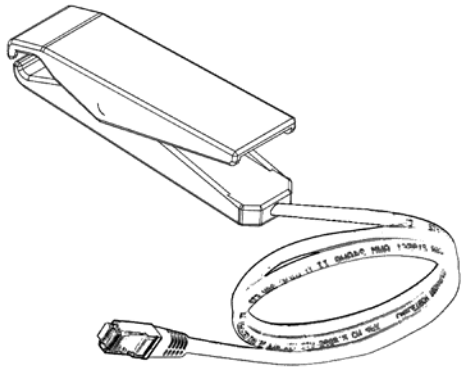

Figure 5 – External Probe

5.0 SYSTEM ARCHITECTURE

5.1 SYSTEM MICROCONTROLLER (MCU)

The *RT30* shall use the Microchip PIC16F677 flash MCU, based on the Microchip's 14-bit RISC architecture, for both the TU and RU master controllers. The PIC16F677 was chosen for its combination of low power operation, low cost, and system flexibility.

Features of the PIC16F677 include:

- 4KB of on-board Flash ROM
- 128 bytes of on-board "scratchpad" RAM
- 256 bytes of on-board EEPROM
- sub-250µA operating current
- internal programmable SPI/I^2C port
- on-board oscillator with 2% accuracy
- internal 8- and 16-bit timers with pre-scaling
- internal power-up and "watchdog" timers
- up to 12 analog inputs
- up to 18 general-purpose I/O (GPIO) lines (1)
- 20-pin DIP, SOIC, and SSOP packaging
- sub- and superset parts available

Notes: 1. Use of other built-in features takes away from this "pool" of available GPIOs.

5.1.1 TU I/O Port Usage

Port	Pin #	Direction	Signal	Description
RA0	19	n/a	ICPDAT	Programming use only
RA1	18	n/a	ICPCLK	Programming use only
RA2	17	Out	DATCE	nRF905 TX/RX enable
RA3	4	n/a	ICVPP	Programming use only
RA4	3	In	EXTALG	External Analog input (1,2)
RA5	2	In	SWIN	Mode Switch input
RB4	13	In	RFRX	SPI port MISO
RB5	12	In	DRDY	nRF905 Data Ready
RB6	11	Out	RFCLK	SPI port clock
RB7	10	Out	RFCS	nRF905 Command Enable
RC0	16	In	CALIN	Calibrate/Channel Switch
RC1	15	In	LDRIN	Light Resistor input (2)
RC2	14	In	EXPDET	External Probe Detect
RC3	7	Out	EXPLED	Expansion LED (1)
RC4	6	Out	ALMLED	Detect LED
RC5	5	In	SENSIN	Internal NCV sensor
RC6	8	In	EXPIN	External NCV sensor
RC7	9	Out	RFTX	SPI port MOSI

Notes:
1. Future expansion.
2. Analog input.

5.1.2 RU I/O Port Usage

Port	Pin #	Direction	Signal	Description
RA0	19	n/a	ICPDAT	Programming use only
RA1	18	n/a	ICPCLK	Programming use only
RA2	17	Out	DATCE	nRF905 TX/RX enable
RA3	4	n/a	ICVPP	Programming use only
RA4	3	In	SPIO1	Reserved (1)
RA5	2	In	SWIN	Mode Switch input
RB4	13	In	RFRX	SPI port MISO
RB5	12	In	DRDY	nRF905 Data Ready
RB6	11	Out	RFCLK	SPI port clock
RB7	10	Out	RFCS	nRF905 Command Enable
RC0	16	In	RFDET	nRF905 RF Detect
RC1	15	In	ADDROK	nRF905 Address Match
RC2	14	In	TRIPLED	Detect LED
RC3	7	Out	BUZZER	Piezo Buzzer driver (2)
RC4	6	Out	BUZZER	Piezo Buzzer driver (2)
RC5	5	Out	RFLED	Communication LED
RC6	8	Out	BUZZER	Piezo Buzzer driver (2)
RC7	9	Out	RFTX	SPI port MOSI

Notes:
1. Future expansion.
2. These lines are paralleled to satisfy the drive requirements of the buzzer.

5.1.3 System ROM

The *RT30* TU and RU will use the built-in 4KB (2K words) Flash ROM of the PIC16F677 to store execution code for the MCU. This memory is re-programmable in the system, using an on-board connector.

5.1.4 System RAM

The *RT30* TU and RU will use the built-in 128 bytes of RAM in the PIC16F677.

5.1.5 EEPROM

The *RT30* TU and RU will use the PIC16F677's built-in 256 bytes of EEPROM for any necessary non-volatile storage.

5.2 RF SYSTEM CONTROLLER

The *RT30* shall use the Nordic Semiconductor nRF905 for both the TU and RU RF system controllers. The nRF905 was chosen for its combination of low power operation, minimal overhead, and system flexibility.

Features of the nRF905 include:

- 433MHz, 868MHz, or 915MHz band
- proprietary ShockBurst™ low-power operation
- 32-bit addressing minimizes false communication
- automatic generation of 8/16-bit CRC
- SPI port communication
- low-power standby mode
- programmable output power and frequency
- 32-pin QLCC package

5.2.1 RF System Settings

The two nRF905 devices shall be programmed to use the following parameters:

Center Frequency	869.0MHz (EU version) 914.0MHz (NA version)
Channel Spacing	0.6MHz
Transmission Power	+10dBm (10mW)
Transmission Mode	ShockBurst
Transmission Length	< 3mS (Standard) < 8mS (Extended) (1)
Transmission Period	250mS
Receiver Mode	Normal
Preamble Size	10-bit (2)
Address Size	32-bit
Command Size	8-bit
Standard Data Size	24-bit
Extended Data Size	232-bit (29 bytes)
Checksum	CRC-16

Notes: 1. Extended transmission is not supported at this time.
2. Fixed value defined in the nRF905.

5.2.2 Communications Scheme

All communications shall follow the conventions defined in the Extech specification, *Inter-Module RF Communications Rev 1.2*.

5.2.2.1 Device Address

The working address for all *RT30* devices shall be 45583730h ('EX30' ASCII).

5.2.2.2 Supported Commands

While the *RT30* shall accept *all* commands defined in the *Inter-Module RF Communications* specification without system failure, the TU shall only send, and the RU shall only act upon, the following commands:

- Alarm Status
- Beep Code
- Hello
- Comm Channel Change

5.3 SWITCHES

5.3.1 TU Power/Mode Switch

This switch has three positions:

- **Off** – The unit is off, and battery power is completely disabled.
- **NCV** – The internal NCV circuit is enabled. This setting can be overridden by attaching the External Probe.
- **Light** – The LDR circuit is enabled. This setting can also be overridden by attaching the External Probe.

5.3.2 TU Calibrate/Channel Switch

This switch is a momentary switch. It has two functions:

- **Calibrate** – If the switch is pressed for more than 100mS, but less than 5 seconds, the *RT30* shall enter Calibrate Mode. A 'short' press is also used to select channels.
- **Channel** – If the switch is pressed for more than 10 seconds, the *RT30* shall enter Channel Select mode.

5.3.3 RU Power/Mode Switch

This switch has three positions:

- **Off** – The unit is off, and battery power is completely disabled.
- **On** – The receiver is on, and the Beeper is enabled.
- **Silent** – The receiver is on, but the Beeper is disabled from announcing alarm conditions. Beep codes for auxiliary functions shall still be sent.

5.4 INDICATORS

5.4.1 TU Indicators

The TU has two LED indicators:

- **Power LED (Green)** – This indicator shows that the TU is operating, and has battery power.
- **Detect LED (Amber)** – This indicator shows that the TU has detected voltage (when in NCV or External Mode) or a light level change (when in Light Mode).

5.4.2 Auxiliary TU Indications

- **Startup** – During initial power-up, the TU shall test the communications between the MCU and the RF System. If successful, the Detect LED shall briefly light and then go out.
- **EEPROM Init** – If the EEPROM memory is corrupt or not yet programmed, the MCU shall re-program the data and clear all unused locations. During this process, the Detect LED shall briefly flicker at a > 5Hz rate. Under normal circumstances, this indication shall only occur after the MCU is programmed.
- **Channel Select** – The Detect LED shall flash at a 2Hz rate.

5.4.3 RU Indicators

The RU has three LED indicators:

- **Power LED (Green)** – This indicator shows that the RU is operating, and has battery power.
- **Detect LED (Amber)** – When a wireless connection is present, this indicator is a mirror image of the TU's Detect LED. It shows that the TU has detected voltage (when in NCV or External Mode) or a light level change (when in Light Mode).
- **Communication LED (Yellow)** – This indicator shows that the TU and RU are in communication.

5.4.4 Auxiliary TU Indications

- **Startup** – During initial power-up, the RU shall test the communications between the MCU and the RF System. If successful, the Detect and Communication LEDs shall briefly light and then go out.
- **EEPROM Init** – If the EEPROM memory is corrupt or not yet programmed, the MCU shall re-program the data and clear all unused locations. During this process, the Detect and Communication LEDs shall briefly flicker at a > 5Hz rate. Under normal circumstances, this indication shall only occur after the MCU is programmed.

5.5 FIRMWARE CONTROL SEQUENCES

5.5.1 Calibrating the Light Meter (TU)

On power-up, the TU shall assume that the ambient light level is a "no alarm" condition. If the TU is powered on in a brightly-lit room, it shall assume *less* light is an alarm condition; if it is powered on in a dark room, it shall assume *more* light is an alarm. To change this operation, or adjust for changes in background light levels, the follow sequence shall be used:

- Press the Calibrate/Channel Switch briefly (approx. 0.5-1.0 second). If the RU is in communication, its Detect LED and Beeper shall also turn off.
- Upon releasing the switch, the light level seen by the Light Detector shall become the 'no alarm' condition, and the RU shall beep twice to confirm the calibration.
- The TU shall inhibit detection of alarms for 2-3 seconds after calibration is complete, to allow the user to adjust the position of the TU.

Note: The Light Meter can be calibrated with the TU's Power/Mode Switch in either the NCV or Light position.

5.5.2 Changing the Wireless Channel

The *RT30* can operate on one of three (3) adjacent RF channels. To change to another channel:

1. Press the Calibrate/Channel Switch on the TU until the Detect LED flashes the Channel Select sequence defined in Section 5.4.2 (at least 10 seconds).
2. Any connected RU shall beep a number corresponding to the current channel of the TU. If this is the correct channel, move to Step 4.
3. Press the Calibrate/Channel Switch briefly (~0.5 second) again. The TU and RU(s) shall move to the next channel in the following round-robin order: CH1 → CH2 → CH3 → CH1, etc. The RU shall beep a number corresponding to the new channel number.
4. Once the TU and RU(s) are on the correct channel, press the Calibrate/Channel Switch for at least 10 seconds again. The new channel is now stored in both the TU and RU. The RU shall beep a number corresponding to the new channel number again to confirm the action.

5.5.3 Synchronizing 'Lost' RUs

If an RU is not programmed to the same channel as the TU, it can be synchronized in the same manner. During the Channel Select process, the TU shall send out a message on all three channels, instructing any listening RU to move to the TU's channel.

Ex: TU is on CH3. RU #1 is on CH2. RU #2 is on CH1.

1. Press the Calibrate/Channel Switch for 5 seconds.
2. RU #1 and #2 *both* beep three times. All devices are now on CH3, and the Communication LEDs are lit.

3. Press the Calibrate/Channel Switch for 0.5 second.
4. RU #1 and #2 both beep once. All devices are now on CH1.
5. Press the Calibrate/Channel Switch for 0.5 second.
6. RU #1 and #2 both beep twice. All devices are now on CH2.

7. Press the Calibrate/Channel Switch for 3 seconds.
8. RU #1 and #2 both beep twice. All devices are now programmed to CH2.

Note: While several RUs can be used with one TU, use of multiple TUs with a single RU is not guaranteed to work, due to potential wireless communication interference.

5.5.4 RU Power Management

The RU shall be required to sync to any incoming message; therefore, significant power management is not possible during the 'active' state.

To maximize battery life, an RU that has not received a transmission from the TU for 30 minutes shall enter a power-saving mode:

- The nRF905 shall be disabled.
- All indicators except the Power LED shall be disabled.
- The RU shall beep once every 20 seconds to denote the power-saving mode.

Once the RU has entered this mode, it must be turned off and on again to return to normal operation.

5.5.5 TU Power Management

The TU shall implement full-time power management of the RF transmitter, its greatest power sink. The nRF905 shall be disabled at the end of each transmission, reducing the power consumption by 80-90%. Because of the minimal transmission rate of the TU (duty cycle ~1%), the RF system shall thus be in low-power mode most of the time.

6.0 POWER

6.1 BATTERIES

Both the TU and RU shall use standard 'AAA' batteries (MN2400 or equivalent). The battery compartments shall be accessible through a battery door with a Philips-head locking screw. There shall be adequate markings on the case and/or PC board to denote the polarity of each battery, as shown in Figure 6.

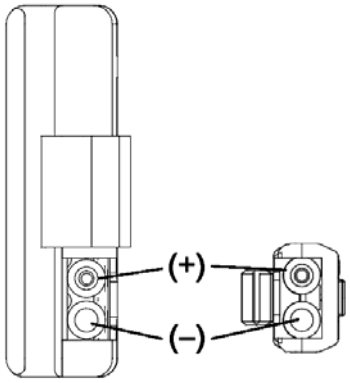

Figure 6 – Battery Installation

The External Probe shall not require battery power, but shall obtain power through its cable.

6.2 DC/DC CONVERTER

Both the TU and RU shall use a low-dropout (LDO) linear regulator to provide 2.5V for the system.

7.0 EXTERNAL CONNECTORS

7.1 EXTERNAL PROBE CONNECTOR

The External Probe Connector shall be a standard RJ45-8 unshielded connector, without indicators.

Pin #	Signal Name	Direction	Description
1	GND	-	Signal Ground
2	EXPDET	In	External Probe Detect
3	EXPINB	In	External Probe Input
4	ICPVPPB	In	Programming Vpp
5	ICPDATB	I/O	Programming Data
6	ICPCLKB	In	Programming Clock
7	EXTALGB	In	External Analog Input (1)
8	GND	-	Signal Ground

Notes: 1. Future expansion.

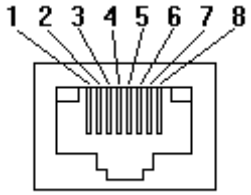

Figure 7 – External Probe Connector

8.0 MISCELLANEOUS SPECIFICATIONS

8.1 DROP TEST

The *RT30* shall be capable of withstanding a 1.5m drop, per ISTA #2a. The test includes one drop onto the weakest corner, one drop onto each edge radiating from that corner, and one drop on each face of the meter, all onto a flat, rigid base such as steel or concrete.

8.2 RESISTANCE TO CONTAMINATION

Both the TU and RU shall be protected to the IP43 standards (protected against solid objects > $1mm^3$, direct sprays of water ± 60° from vertical).

8.3 COLOR

The *RT30* shall be molded in the standard Extech colors of Pantone 021 Orange and Pantone 3435 Green. Color matching shall be approved by Extech Engineering.

8.4 SERIAL NUMBERING

The *RT30* TU and RU shall each have a (physical) external serial number label on the back side of the case. Details of the label are TBD.

8.5 LOGO LABELING

The standard Extech Instruments logo, as shown in Figure 8, shall be plainly displayed on the front of the unit.

Figure 8 – Extech Logo

9.0 AGENCY APPROVALS

9.1 SAFETY

The following safety approvals shall be obtained:

- UL Listing
- CE Mark

9.2 EMC

The following electromagnetic compatibility (EMC) approvals shall be obtained:

- FCC CFR 47, Part 15 Class B
- CISPR Publication 22 Class B

9.3 RF TRANSMITTER

The following low-power RF transmission approvals shall be obtained:

- FCC CFR 47, Part 15
- CISPR Publication 22

10.0 REVISION HISTORY

REVISION	DATE	DESCRIPTION/CHANGES
A	4 Jan 2008	INITIAL RELEASE
B	7 Jan 2008	Added power management definitions; changed to 1-step Calibration

APPENDIX A – APPLICABLE AGENCY STANDARDS

The following national and international standards apply to this product.

Document	Country	Description
ANSI C63.4 – 1992	USA	"American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz", American National Standards Institute (ANSI), 1992.
C.I.S.P.R. Pub. 22	Europe	"Limits and Methods of Measurement of Radio Interference Characteristics of Information Technology Equipment", International Special Committee on Radio Interference (C.I.S.P.R), Second Edition, 1993.
CFR 47, Part 15	USA	"Unintentional Radiators", Title 47 of the Code of Federal Regulations, Part 15, FCC Rules, Radio Frequency Devices, Subpart B.
UL 94	USA	“Standard for Safety for Test for Flammability of Plastic Materials for Parts in Devices and Appliances,” Fifth Edition. Underwriters Laboratories Inc., 1996.
UL 796	USA	“Standard for Safety for Printed-Wiring Boards,” Eighth Edition. Underwriters Laboratories Inc., 1999.