EMU-2™
Energy Monitoring Unit

Technical Manual

Version 1.05
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RFA-Z105-2
Version 1.05

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Regulatory information

FCC Notices

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. Changes or modifications not expressly approved by the manufacturer could void the user's authority to operate the equipment.

FCC/IC RF Exposure Statement

This equipment complies with FCC and Industry Canada radiation exposure limits set forth for an uncontrolled environment. The antenna(s) used for this equipment must be installed to provide a separation distance of at least 8 inches (20cm) from all persons.

ICES-003 Compliance

This Class B digital apparatus complies with Canadian ICES-003.

Note: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Compliance Regulations For Australia and New Zealand

This equipment complies with the C-Tick labeling requirements for Australia and in New Zealand. As a radio transmitter, this device complies with the requirements of AS/NZS 4268:2008 as designated in the Radiocommunications (Short Range Devices) Standard 2004 for Australia and as required by the Radiocommunications Regulations (General Users Radio License for Short Range Devices) Notice 2011 for New Zealand. This device is a Category A device as defined in the Radiocommunications (Compliance Labeling - Electromagnetic Radiation) Notice 2003.

About This Manual

This manual is intended for those needing detailed technical information about the **EMU-2™** product, such as customer support engineers and laboratory and field engineers performing evaluations and trials involving the **EMU-2™**. This manual is a companion to the *EMU-2™ User Manual*, and both documents should be consulted.

None of the information contained in this manual should be required by the average consumer to operate the **EMU-2™** product under normal conditions.

About the EMU-2™

The **EMU-2™** is a ZigBee endpoint that acts as an In-Home Display. It implements the ZigBee Smart Energy Profile 1.1. The supported clusters are shown below.

The Active Mode and Configuration Mode screens are described in detail in the *EMU-2™ User Manual*. This manual provides information about Diagnostic Mode, which is not intended to be used by non-technical users.

Supported Clusters

Cluster	Cluster ID	Client/ Server	Commands	Cmd ID	Attribute Set	AttSet ID	Attributes read	Attribute ID	Option
Basic	0x0000	Server	*Mandatory Commands*						
Identify	0x0003	Server	*Mandatory Commands*						
Time	0x000a	Client	Read Attributes	0x00			Time	0x0000	
							TimeStatus	0x0001	
							LocalTime	0x0007	
Key Establishment	0x0800	Client/ Server	*Mandatory Commands*						
Simple Metering	0x0702	Client	GetProfile	0x00					
			GetProfileResponse (received)	0x00			EndTime		
							Status		
							ProfileIntervalPeriod		
							NumberOfPeriodsDelivered		
							Intervals		
			Read Attributes	0x00	Reading Information	0x00	CurrentSummationDelivered	0x00	
							CurrentSummationReceived	0x01	
							CurrentBlockPeriodConsumptionDelivered	0x0c	Block Price
					Meter Status	0x02	Status	0x00	
					Formatting	0x03	UnitofMeasure	0x00	
							Multiplier	0x01	
							Divisor	0x02	
							SummationFormatting	0x03	
							DemandFormatting	0x04	
							MeteringDeviceType	0x06	
					Historical Consumption	0x04	InstantaneousDemand	0x00	

Cluster	Cluster ID	Client/ Server	Commands	Cmd ID	Attribute Set	AttSet ID	Attributes read	Attribute ID	Option
Price	0x0700	Client	GetCurrentPrice	0x00					
			GetSceduledPrices	0x01					
			PriceAcknowledgement	0x02					
			PublishPrice (received)	0x00			Rate Label		
							Currency		
							Price Trailing Digit and Tier		
							Number Of Price Tiers & Register Tier		
							Start Time		
							Duration		
							Price		
							Number Of Block Thresholds		Block Price
							Price Control		
			Attributes		Tier Label	0x00	Tier1PriceLabel	0x00	Price Label
							Tier2PriceLabel	0x01	
							Tier3PriceLabel	0x02	
							Tier4PriceLabel	0x03	
							Tier5PriceLabel	0x04	
							Tier6PriceLabel	0x05	
							Tier7PriceLabel	0x06	
					Block Threshold	0x01	Block1Threshold	0x00	Block Price
							Block2Threshold	0x01	
							Block3Threshold	0x02	
							Block4Threshold	0x03	
							Block5Threshold	0x04	
					Block Period	0x02	StartOfBlockPeriod	0x00	
							BlockPeriodDuration (minutes)	0x01	
							ThresholdMultiplier	0x02	
							ThresholdDivisor	0x03	
					Commodity	0x03	Standing Charge	0x01	
					Block Price Information	0x04	NoTierBlock1Price	0x00	
							NoTierBlock2Price	0x01	
							NoTierBlock3Price	0x02	
							NoTierBlock4Price	0x03	
							NoTierBlock5Price	0x04	
					Billing Information	0x07	CurrentBillingPeriodStart	0x00	
							CurrentBillingPeriodDuration	0x01	
Message	0x0703	Client	GetLastMessage	0x00					
			Message Confirmation	0x01					
			Cancel Message (received)	0x01			MessageID		
							MessageControl		
			DisplayMessage (received)	0x00			MessageID		
							MessageControl		
							StartTime		
							Duration		
							Message		
Prepayment	0x0703	Client	Attributes		Prepayment Information Set	0x00	Payment Control	0x00	Prepay
							Credit Remaining	0x01	
							Credit Status	0x03	

only enabled for prepayment support — Prepay
only enabled if Price Labels are used instead of Rate Label — Price Label
only enabled for block pricing support — Block Price

Startup Procedure

Once the **EMU-2™** has successfully completed its initialization procedures, the display will show the *Startup* screen. Normally, this is the Rainforest Automation logo:

Then the Joining Procedure will begin.

The procedure is as follows:

- Send Beacon Request, and look for a device that has the 'join' flag enabled in its beacon.

- After joining the network, wait for the Coordinator to send the network key encrypted with our link key (derived from the install code).

- Look for the Key Establishment Cluster using match descriptor.

- Perform Key Exchange.

- If successful, look for the time cluster and the metering cluster.

- If successful, ask for time. The time needs to be a valid value.

- If successful, ask for metering, pricing, and messaging.

The flowchart for this procedure is shown below, along with the output screens that are displayed during the procedure:

```
For each Channel 11 up to 26
    Send Beacon Request                      ⇨   Searching for
                                                 meters
    Receive Beacons, make list of
    Candidates
    For each Candidate
        Try to Join                          ⇨   Connecting to Meter
                                                 Please Wait...
            Joined?
        N              Y
                Key Exchange
                    Success?
                N              Y
                    Get Meter Data
                        Success?
                    N          Y
                            Exit
    Next Candidate
    Next Channel
Start Again
```

Active Mode
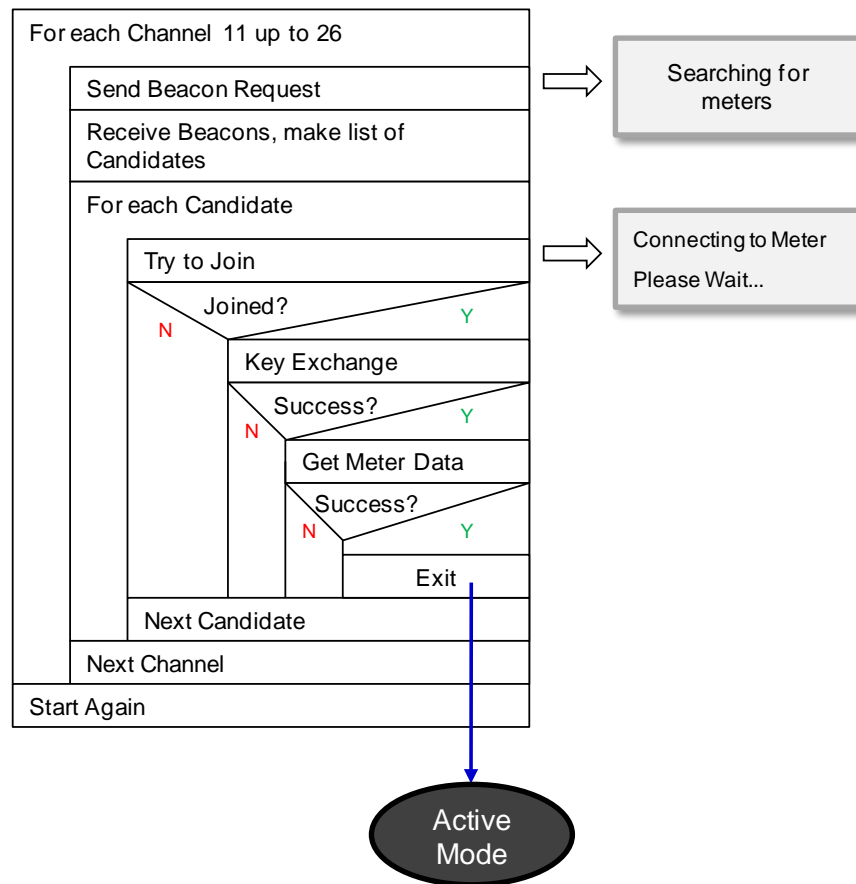
The Joining Procedure is repeated continuously, cycling through all the channels (11-26), looking for candidates to join.

It is important that the device not be restarted during the Joining Procedure. This has unpredictable results, and may cause the device to be decommissioned, as if it had performed a Hard Reset.

Diagnostic Mode

Diagnostic Mode provides a number of screens that give you technical details about the **EMU-2**™, and also provide access to advanced functions, such as Hard Reset and Firmware Update.

To get into Diagnostic Mode, you must first put the **EMU-2**™ into Configuration Mode. This is done by pressing and releasing both buttons simultaneously (note that this should not be attempted until the **EMU-2**™ has successfully connected to the smart meter). Once in Configuration Mode, hold down both buttons for at least five seconds. When the buttons are released, Diagnostic Mode will be initiated.

Note that the unit will automatically return to Active Mode after one minute of inactivity.

Diagnostic Mode Navigation Flowchart

Configuration Mode — both buttons → **Active Mode** — any button → **Sleep Mode**

Active Mode — 1 minute inactivity → **Configuration Mode**

4 minutes inactivity (Active ↔ Sleep)

Configuration Mode — hold both buttons for 5 seconds, release → **Diagnostic Mode**

Diagnostic Mode — 1 minute inactivity → **Active Mode**

Diagnostic Mode → *Hard Reset* screen

Hard Reset screen — Top Button → **Disconnect from meter**

Hard Reset screen — Bottom Button → *Device ID* screen

Device ID screen — any button → *Link Key* screen

Link Key screen — any button → *Device info* screen

Device info screen — any button → **Active Mode**

EMU-2™ Diagnostic Mode Screens

Hard Reset

The *Hard Reset* screen allows you to perform a Hard Reset by pressing the Top Button. Pressing the Bottom Button sends you to the *Device ID* screen.

> Hard Reset?
> Reset ➡
> Skip ➡

Device ID

The *Device ID* screen shows the Install Code (IN) and MAC Address (MAC) for this particular device. Both are 16 digit hex numbers. Pressing any button sends you to the *Link Key* screen.

> Device ID
> IN:ee6d785b8006db6d
> MAC:00158d00001a56d7

Link Key

The *Link Key* screen shows the Preconfigured Link Key for this **EMU-2**™. It consists of 16 pairs of hex digits. Pressing any button sends you to the *Device Info* screen.

> Link Key
> 78:af:a4:da:a3:e9:0b:24
> 9d:15:20:0e:da:a8:74:d2

Device Info

The *Device Info* screen shows the revision number of the firmware (FW) installed on the device, as well as the hardware version (HW) of the **EMU-2**™. Pressing any button sends you to Active Mode.

> Device Info
> HW: 3.0.1
> FW: 1.2.12 (3094)

Hard Reset

A Hard Reset will erase all existing data and configurations on the **EMU-2**™. The device will be decommissioned and will not be able to immediately rejoin the smart meter. The smart meter will not allow the **EMU-2**™ to join until the meter has also decommissioned the **EMU-2**™, and then reregistered **EMU-2**™ for joining.

A Hard Reset can be initiated from the *Hard Reset* screen in Diagnostic Mode (see the previous section, "Diagnostic Mode"). Selecting "Reset" (Top Button) in the *Hard Reset* screen brings up the following screen that confirms that you intend to perform a Hard Reset and disconnect from the meter:

> Are you sure?
> Disconnect from meter ➡
> Cancel ➡
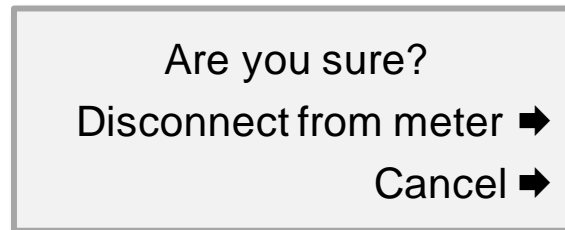
Pressing "Cancel" (Bottom Button) will abort the process and send you to Active Mode. Pressing the Top Button will erase all existing data and configurations, disconnect from the meter, and reset the **EMU-2**™.

Connecting to the Serial Port

You can connect your Windows computer to the **EMU-2™** serial port. This will allow you to access the real time meter data directly, and will also let you program in complex pricing structures, and even update the internal firmware to enable new features.

The serial port is a Mini USB port, found above the power socket on the side of the **EMU-2™**. You will need a cable (like those typically used for digital cameras) to connect this port on the **EMU-2™** to the USB port of your Windows computer.

Your computer should be running Windows 7 or greater. It must also have the .NET Framework (ver 2.0 or greater) installed. If .NET is not installed on your computer, you will be prompted to download it during the software installation procedure.

Before connecting the **EMU-2™** to your computer, you will need to install the *Personal Meter Reader*™ software.

Go to the link: http://www.rainforestautomation.com/raven_support

Click on the *Personal Meter Reader*™ link to download the software.

Save the .ZIP file when prompted. Extract the files in the .ZIP folder. Double click on the application file named "setup.exe".

Note that this installation requires that you have the necessary permissions to install programs on your hard drive. You may need Power User/Admin permissions.

You must agree to run the install when you are prompted to do so. You will see the Welcome screen for the Setup Wizard. Click on "Next" and follow the onscreen directions to complete the installation of the software.

When the software installation is complete, there will be a new icon on your desktop that is a shortcut to the *Personal Meter Reader*™ software.

Launch the application by double clicking on the icon. After a moment you will see the *Personal Meter Reader*™ window.
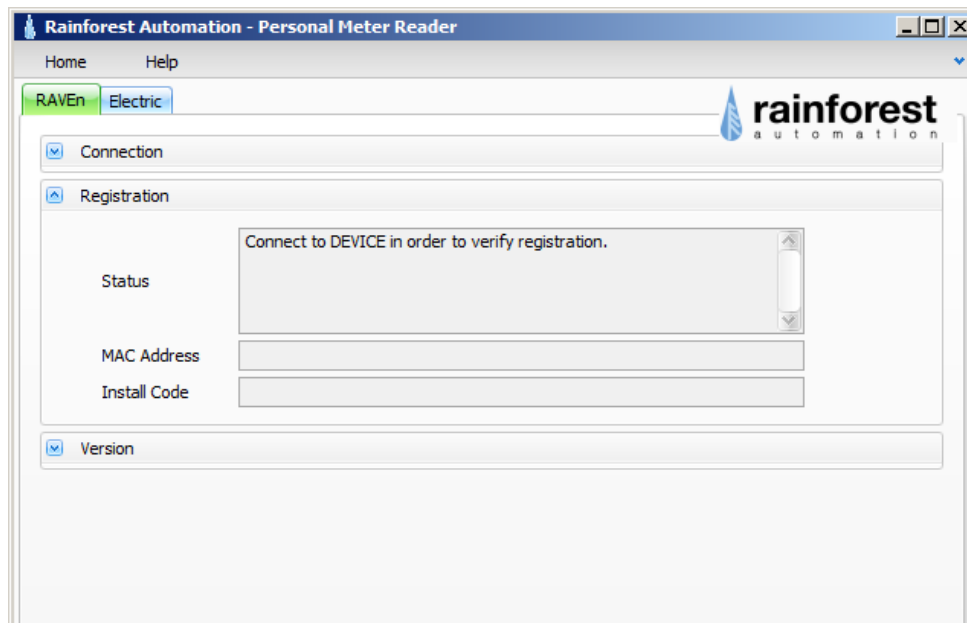
Ensure that the **EMU-2™** is powered only by its AC adapter, and there are <u>no batteries installed</u>; *power from the batteries may interfere with operation of the USB port.*

Connect the device to your computer using the Mini USB cable. When the **EMU-2™** is plugged in for the first time, the device drivers have to be installed. This should be done automatically by Windows. If, for some reason, Windows is unable to find the drivers, you will need to install them manually. The drivers are available for download at: http://www.rainforestautomation.com/developer.

In the *Personal Meter Reader™* program, click the blue button to the left of "Connection" to expand the box.
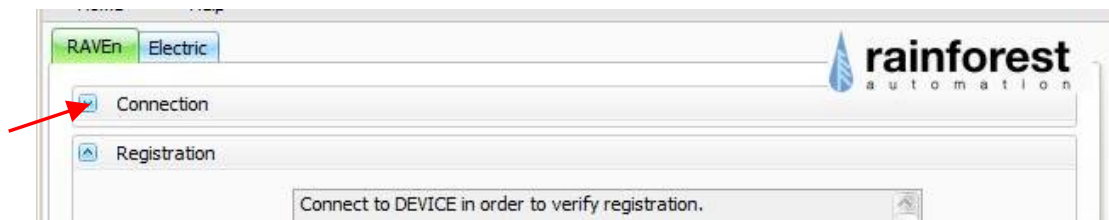
You will see the Serial Port connection information.
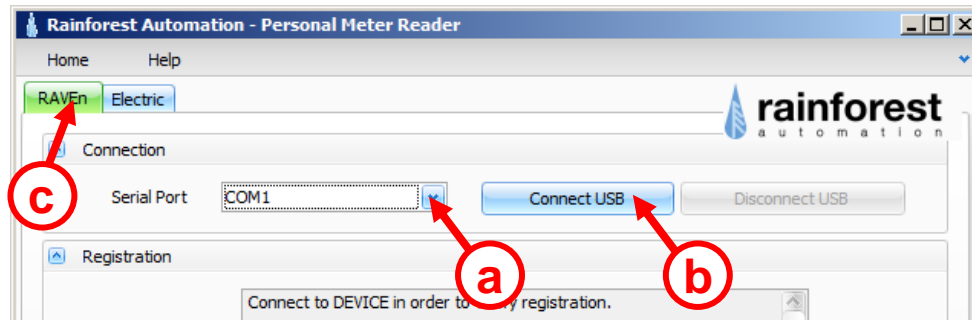
(a) Select the serial COM port corresponding to the USB port you have plugged the **EMU-2™** into. You may have to check with your Windows Device Manager to determine this.

(b) Click the "Connect USB" button to initiate the connection. You should see the "speedometer" screen pop up.

(c) Click the green "RAVEn" tab to get back to the device information. You should see that the "Disconnect USB" button is now highlighted in blue, and the "Connect USB" button is greyed out. After a few moments, the "Registration" box should display the MAC Address and Install Code for the device.

Your computer is now communicating with the **EMU-2™**.

Firmware Update

A Firmware Update will replace all of the application code contained in the program memory of the **EMU-2™**. The update code is loaded into the **EMU-2™** using the serial port and the *Personal Meter Reader™* software. You will need to follow the directions in the previous section, "Connecting to the Serial Port".

Once your computer is connected to the **EMU-2™**, click the "Home" tab at the top of the *Personal Meter Reader™* screen, and select "Firmware".
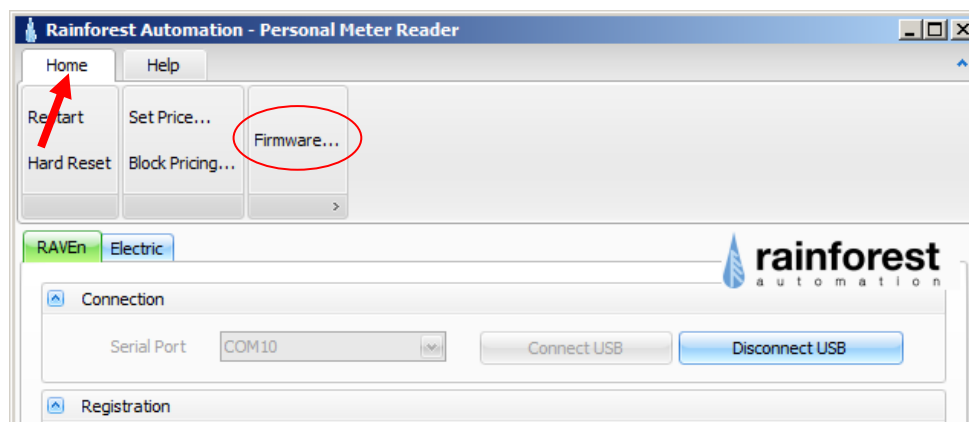
The "Firmware Update" window should pop up.
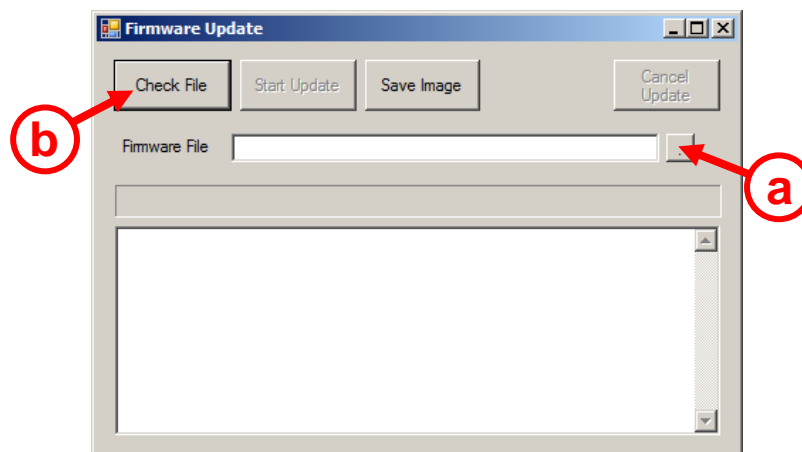
(a) Click the button to the right of the "Firmware File" field. You should be able to browse to the .zigbee file that contains the updated code image. Once you have selected it, the file name should appear in the "Firmware File" field.

(b) Click the "Check File" button. You will see several lines of info appear in the lower half of the window, ending with, "Check File complete."
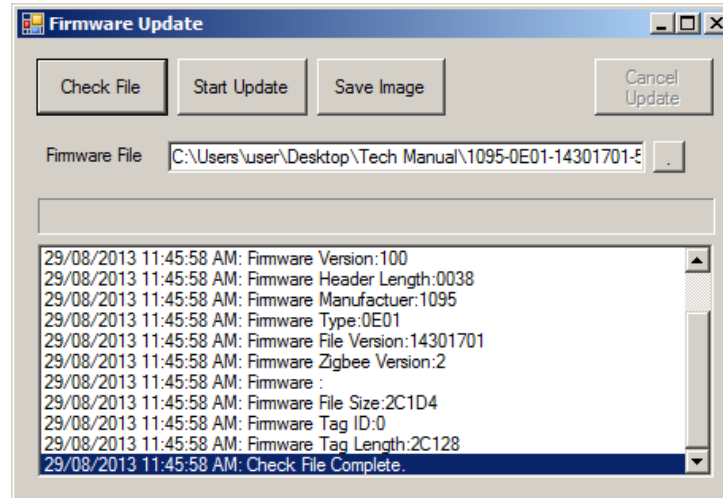
If the **EMU-2™** is joined to a meter, then press one of the buttons until the *Current Time* screen is shown. If it is not joined to a meter, the **EMU-2™** will be very busy trying to find and connect; this will slow down the communication on the serial port. To prevent this, put the **EMU-2™** into Configuration Mode by simultaneously pressing and releasing both buttons. This will temporarily halt the meter search activity until it times out after 1 minute. If you keep the unit in Configuration Mode, it will speed up the download of the Firmware Update.

Click the "Start Update" button in the "Firmware Update" window. You will see the line, "Update Firmware Started" appear in the lower half of the window. The progress bar across the center of the window will fill over and over, many times. It will take at least 16 minutes to load the new firmware. Do not unplug the device during this process.

When the download is done, the message, "Firmware download complete; switching to new firmware" will appear at the bottom of the window. The device will then be reset, and the new firmware version will be verified. When you see the message, "Firmware is x.x.xx…", then the process is complete.

LED indication (TOU build)

The **EMU-2™** has three Indicator LED Lights arranged in a "stoplight" pattern; that is, red at the top, yellow in the middle, and green at the bottom.

When the **EMU-2™** firmware is factory-configured for a TOU build, these lights indicate the current price tier. There can be up to 7 price tiers. For most tiers, a single light will be on.

The top tier is always considered Critical Peak, and is indicated by a double flash of the Red LED every 3 seconds.

If the number of tiers is 1 or 0, or if the price tier has not been set, then none of the Indicator LED Lights will be on.

# of tiers	tier 1	tier 2	tier 3	tier 4	tier 5	tier 6	tier 7
7	green	green	yellow	yellow	red	red	flashing red
6	green	green	yellow	yellow	red	flashing red	
5	green	yellow	red	red	flashing red		
4	green	yellow	red	flashing red			
3	green	yellow	flashing red				
2	green	flashing red					
1							
0							

If the price is set manually using the *Set Rate* screen, none of the Indicator LED Lights will be on while the manually set price is in effect.

Note that the Indicator LED Lights are also used to indicate that a new text message has been received. In that case, the Red and Yellow LEDs will flash alternatively.

LED indication (Demand build)

The **EMU-2™** has three Indicator LED Lights arranged in a "stoplight" pattern; that is, red at the top, yellow in the middle, and green at the bottom.

When the **EMU-2™** firmware is factory-configured for a Demand build, these lights indicate the current rate of demand for power (in kW) relative to a baseline.

The baseline is initially set to 0.5 kW, but can be changed while in the *Current Usage* screen. To set the baseline:

- Navigate to the *Current Usage* screen using the device control buttons.

- Adjust your usage by switching loads in your house on or off, until the *Current Usage* screen shows the value you want to use for the baseline.

- Press and hold the Top Button for 5 seconds. You should see all three Indicator LED Lights come on together. This indicates that the baseline has been set to the current usage rate shown on the screen.

After that, the Green light will be on when the current consumption rate is below the baseline. When consumption is at the baseline rate or greater (up to 5x the baseline rate), the Yellow light will be on. When consumption is more than 5x the baseline rate, the Red light will be on.
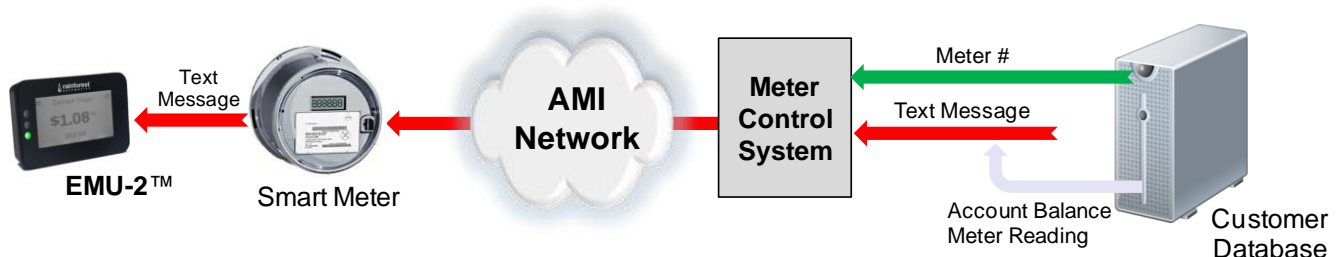
Prepay Support

A firmware option is available for **EMU-2™** to read the Prepayment Cluster (see the Supported Clusters diagram in the "About the EMU-2" section in this manual). If this is enabled in the firmware build, then the *Prepayment Information* attribute set is read from the meter. If the meter provides this information, then a new *Prepaid Balance* screen is shown between the *Current Price* screen and the *Message* screen:
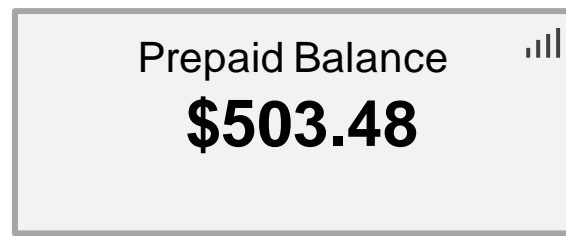
If the meter does not support the Prepayment Cluster, the **EMU-2™** can still receive the *Prepaid Balance* information by using specially formatted text messages. This technique is called Message Tunneling. A text message can be sent to the Meter Control System, containing the account balance information, as well as a time stamp and corresponding meter reading, along with the appropriate meter number. The Meter Control System can forward the text message in the usual way to the meter, and the meter will deliver the text message via ZigBee to the **EMU-2™**.

If Message Tunneling support is enabled in the **EMU-2™**, then the incoming text message is scanned, looking for the following pattern:

PREPAID BALANCE= $xxx.xx **(**mm/dd/yyyy**-**hh:mm:ss**)** zzzzz**kWh**

Where:
- *xxx.xx* is the account balance in dollars
- *mm/dd/yyyy-hh:mm:ss* is the date and time stamp
- *zzzzz* is the last 5 digits of the meter reading

The information in the text message provides the data necessary for the **EMU-2™** to provide the *Prepaid Balance* screen. The **EMU-2™** can even estimate the up-to-date

instantaneous balance between text message updates by calculating the difference in the meter reading from the last update, multiplying it by the effective price, and subtracting this from the last update balance.

Price Input Options

The **EMU-2**™ provides a number of methods to allow the input of a value for the commodity Price. This flexibility allows it to work with a variety of smart meter deployment configurations.

There is a hierarchy of Price input methods. Listed highest priority first, they are:

1) Meter Price Cluster support – this input overrides any of the others.

2) Text Message parsing – this input overrides manual input.

3) Manual input – this is the default for most deployments.

This hierarchy makes it easy to migrate from the simplest type of meter deployment (no Price support in the meter) to more sophisticated Price options with no changes to the **EMU-2**™.

Manual Input

For smart meter deployments with no pricing in the meter, the users can simply enter the commodity price themselves using the *Set Rate* screen in Configuration Mode, as described in the *EMU-2™ User Manual*. Besides being prone to user error, this method is only really practical for flat rate tariffs.

Text Message Input

A firmware option is available for **EMU-2**™ to allow the commodity Price and Price Tier to be set (simulating a Price Cluster *PublishPrice* Command) using specially formatted text messages. This technique is called Message Tunneling, and is much the same as alternative method for Prepay support mentioned in the "Prepay Support" section of this manual.

If Message Tunneling support is enabled in the **EMU-2**™, then the incoming text message is scanned, looking for the following pattern

CURRENT TIER *y*=**$***x.xxxx***/kWh**

Where:
- *y* is the Price Tier (1-5)
- x.xxxx is the Price in dollars ($0.0000 - $9.9999)

Using this method will overwrite any Price value that has been set manually using the *Set Rate* screen.

This method is particularly useful for implementing dynamic and/or tiered pricing in deployments where the price cluster has not been enabled in the meters. Note that this feature is only available as a special factory option.

Meter Input

The **EMU-2™** issues a GetCurrentPrice command to the meter every 2 minutes. If the meter responds with a PublishPrice Command with pricing information, this new Price value will override any value that has been input manually or via text message. This makes migration to full in-meter pricing transparent and painless.

Serial Port Input

In addition to the three techniques listed above, pricing information can also be programmed into the **EMU-2™** through the USB serial port. This allows complex block pricing schemes, with up to four tiers and programmable block thresholds to be downloaded to the unit. The details of how to use this feature can be found in a separate document: the *EMU-2™ Block Pricing Programming Guide.*