CYCLIC SLEEP MODE

Application Note ***v.1.0***

INTRODUCTION

The purpose of this document is to describe one of the ultra-low power options available with the Laird RM024 RAMP module. The RM024 module includes optimized sleep mode power consumption which makes it an ideal solution for power-restrictive or battery-operated applications. The addition of Cyclic Sleep mode in firmware version v1.3.0 enhances the low-power capabilities by allowing the OEM to program sleep and wake timing parameters to the EEPROM. This eliminates the need for an external host processor to manually issue the sleep commands.

OVERVIEW

The RM024 client radio is the focus for Cyclic Sleep mode power savings since it is normally connected to the remote sensor or device and is often battery powered (requiring the lowest power consumption possible). The server is normally connected in a centralized location with main power or other large power source making the power consumption at the server negligible.

The following are the main features of Cyclic Sleep mode:

- Sleep mode power consumption – 0.93 uA
- Cyclic Sleep mode programming requires only four bytes in the EEPROM
- Cyclic Sleep allows host-less operation with set-and-forget programming of the EEPROM
- RM024 clients maintain synchronization to the server if the sleep cycle is less than two minutes
- Inactivity Counter guarantees that the module remains in Wake cycle if any peripheral is active. The module enters the sleep cycle only after one complete frame of inactivity has passed (this includes RF, UART, GPIO, and AT Command mode activity)
- Sleep cycle can be interrupted using the FORCE_9600 pin

SETUP REQUIREMENTS

Remote sensor applications are best at realizing the power savings that Cyclic Sleep mode can provide. These include alarm monitors, temperature monitors, PLC communication and monitoring, and many more. Any application where periodic monitoring and/or reporting is required can use Cyclic Sleep mode with minimal or no need for external programming and control. This means that the host system connected to the RM024 client can report data over the UART, Digital I/O, or Analog I/O upon waking from sleep and/or receiving a signal from the server over the RF. Remote Digital I/O can be used to signal to the server that the client has entered the Wake cycle.

NOTE: If the host system is connected over the UART and the system data is streaming over the RX line into the RM024 client with no way to stop or disconnect the stream, the RM024 client never enters the Sleep cycle due to the Inactivity Counter.

Table 1: Pins and signals (required and optional)

Required			Optional		
SMT	Pluggable	Signal Name	SMT	Pluggable	Signal Name
9	1	VCC	18	12	CTS (recommended)
10	-	VPA	14	5	uP_RESET
8/11	10	GND	16	15	IN_RANGE
7	2	TX	2	6	SLEEP_INDICATOR (GO_1)
6	3	RX	12	9	SLEEP_INTERRUPT (FORCE_9600)

Table 2: SoEEPROM addresses

Parameter	EEPROM Address/ Setting Bit	Setting Name	Setting Description
REQUIRED (only when Cyclic Sleep is used)			
Sleep Control	0x61 Bit 0	Cyclic Sleep 0 = Disable 1 = Enable	When enabled, Cyclic Sleep mode is active with a Sleep Timer set using EEPROM Addresses 0xCD – 0xCE and a Wake Count set using EEPROM Address 0xCF
Sleep Time High Byte	0xCD	High Byte = 0x00 – 0xFF	The Cyclic mode Sleep Timer is set as a number of cycles Cycle = 31.25ms Max Sleep Time = 0xFFFFdec * 31.25ms = 65535 * 31.25ms ~ 2048 sec
Sleep Time Low Byte	0xCE	Low Byte = 0x01 – 0xFF	The Cyclic mode Sleep Timer is set as a number of cycles Cycle = 31.25ms Max Sleep Time = 0xFFFFdec * 31.25ms = 65535 * 31.25ms ~ 2048 sec
Wake Count	0xCF	Wake Count = 0x01 – 0xFF	The Cyclic mode Wake Counter is set as a number of hop frames to stay awake. Hop frame = 13.19ms Max Wake Counter = 0xFFdec * 13.19ms = 255 * 13.19ms ~ 3.36 sec
OPTIONAL			
Control 0	0x45 Bit 6	Sleep Indicator (GIO_1) 0 = Disable 1 = Enable	When enabled, the RM024 allocates GIO_1 as Sleep_Indicator; Sleep_Indicator asserts low while sleeping and high upon waking. **Note:** This is an optional indication signal that can be used to signal the HOST that the RM024 is in a sleep state.
API Control	0xC1 Bit 6	In_Range High on Wake 0 = Disable 1 = Enable	*Only valid in the client* When enabled, a client initially wakes from a sleep state with In_Range released high. When the client regains synchronization with the server In_Range, it asserts low. **Note:** We recommend that you enable this setting to signal the host when it is safe to send data over the UART interface to the client for transmission, otherwise any data sent over the UART while the client is not synchronized will be discarded.

Table 3: AT Commands

Command Name	Command	Description	Response
OPTIONAL			
Enter AT Mode	0x41 0x54 0x2B 0x2B 0x2B 0x0D	Software command for HOST to enable AT mode *Hardware alternative is to assert the $\overline{\text{CMD/DATA}}$ CMD/DATA pin LOW	0xCC 0x43 0x4F 0x4D
Exit AT Mode	0xCC 0x41 0x54 0x4F 0x0D	Software command for HOST to exit AT mode *Hardware alternative is to release HIGH the $\overline{\text{CMD/DATA}}$ pin	0xCC 0x44 0x41 0x54

Command Name	Command	Description	Response
EEPROM Byte Read	0xCC 0xC0 <start><length> <start> = Start address for Read <length> = # of Bytes to Read	Command can be used by HOST to verify parameter values in the RM024	0xCC <start><length><data read>
EEPROM Byte Write	0xCC 0xC1 <start><length><data> <start> = Start address for Write <length> = # of Bytes to Write <data> = Data to be written	Command can be used by HOST to set up or change parameter values in the RM024	<start><length><last byte written>
Soft Reset	0xCC 0xFF	Software command for HOST to reset the RM024	No Response
Check Status Registry	0xCC 0x00 0x01	The Status Register can be used by the HOST to note error codes in the RM024	0xCC <32-bit Response> <32-bit Response>: Bit 0 – If set, Sleep Crystal failed to start Bit 1 – If set, RM024 was awakened from sleep with Sleep_Inerrupt (Force_9600) pin Bit 2 – If set, last reset was due to Brown-out or Power-on reset; if not set, last reset was due to uP_RESET pin or Soft Reset Bit 3 – If set, Sleep Timer is performing a calibration

USE CASE

This use case assumes an application that wakes once every minute and sends a temperature reading to the RM024 server. The configuration only covers the required settings for the RM024 client and only for enabling and using Cyclic Sleep mode; the remaining configuration required for RM024 server/client communication does not affect Cyclic Sleep mode and is not covered as it depends on the individual application.

Configuration

The hardware design for the RM024 client is a small PCB with the following components. Refer to the RM024 - Hardware Integration Guide for electrical specifications. The guide can be accessed from the Embedded Wireless Solutions Support Center: https://laird-ews-support.desk.com/?b_id=1986#docs

- RM024 client module (pre-configured with EEPROM parameters below)
- AA or AAA battery connector
- 3.3V serial interface

The host system monitors the status of SLEEP_INDICATOR to determine when the module is awake. Once awake, the host system uses the IN_RANGE signal (with In Range High on Wake enabled) as a hardware flow control input signal to determine when the module has regained synchronization with the server and is ready to receive the temperature measurement over the UART.

Warning: If the host system connected to the RM024 client does not monitor the IN_RANGE signal, the RM024 client may not synchronize to the RM024 server when the host system initially tries to send data over the serial interface; this can result in data loss.

Hardware Connections

SMT	Pluggable	RM024 Client Signal	Host System
9	1	VCC	2.3 – 3.6V
10	---	VPA	2.3 – 3.6V
8/11	10	GND	GND
7	2	TX	RX
6	3	RX	TX
2	6	SLEEP_INDICATOR (GO1)	GPIO Input (or possible CTS)
16	15	IN_RANGE	CTS
12	9	SLEEP_INTERRUPT (FORCE_9600)	Optional GPIO Output

EEPROM Setup

The EEPROM settings can be modified over the UART using the associated AT Commands or through the Laird Configuration Utility (additional application-based settings are required for normal operation). Sample configurations for the Server and client are available for download on the Laird website.

Parameter	EEPROM Address/ Setting Bit	Setting	Setting Description
Sleep Control	0x61 Bit 0	0x01	Enabled Cyclic Sleep mode
Sleep Time High Byte	0xCD	0x07	Sleep for 1 minute = 60000ms / 31.25ms = 1920 = 0x0780
Sleep Time Low Byte	0xCE	0x80	See above
Wake Count	0xCF	0x05	Wake for 5 frames, based on 3 TX retries and 2 frames for re-sync to Server * This may need to be adjusted based on testing in operational environment
Control 0	0xC1 Bit 6	1 = Enable	In Range High on Wake enabled
API Control	0x45 bit 6	1 = Enable	GO1 function set as Sleep_Indicator

Battery Life

The calculations below are based on the following information:

2000 mAh battery capacity	Common Battery Chemistries: ▪ Standard AA: ~400-900 mAh ▪ Heavy Duty AA: ~1000-1500 mAh ▪ Rechar NiCd AA: ~500-1100 mAh ▪ Rechar NiMH: ~1300-2900 mAh
5-frame Wake Count	Application monitors SLEEP_INDICATOR and IN_RANGE for reliable data transmission
Number of bytes	10
Number of retries	3
Battery calculations are based on obtaining 50% efficiency from the battery over the life of the battery. Actual results may vary.	

Feature	Description
Average Cyclic Sleep Current	0.93 µA
5-frame Wake Cycle Current (average)	25 mA
10-frame Wake Cycle Current (average)	18.5 mA
Sleep Time	1 minutes = 60,000 ms
Wake Time	5 frames = 58.45 ms

Feature		Description
Average Cyclic Sleep Current		0.93 µA
5-frame Wake Cycle Current (average)		25 mA
5 Frame	Sleep Time/hour	3596551.45 ms = 0.9990421 hour
	Wake Time/hour	3448.55 ms = 0.0009579 hour
	Total Current	(0.9990421 hr * 0.00093 mA) + (0.0009579 hr * 25 mA) = 0.025 mAh
	Battery Life	$\frac{2000\ mAh}{0.025\ mAh}$ = 80000 hrs ≈ 9 year
10 Frame	Sleep Time/hour	3592654.5 ms = 0.99796 hour
	Wake Time/hour	7345.5 ms = 0.00204 hour
	Total Current	(0.99796 hr * 0.00093 mA) + (0.00204 hr * 18.5 mA) = 0.039 mAh
	Battery Life	$\frac{2000\ mAh}{0.039\ mAh}$ = 51282 hrs ≈ 6 year

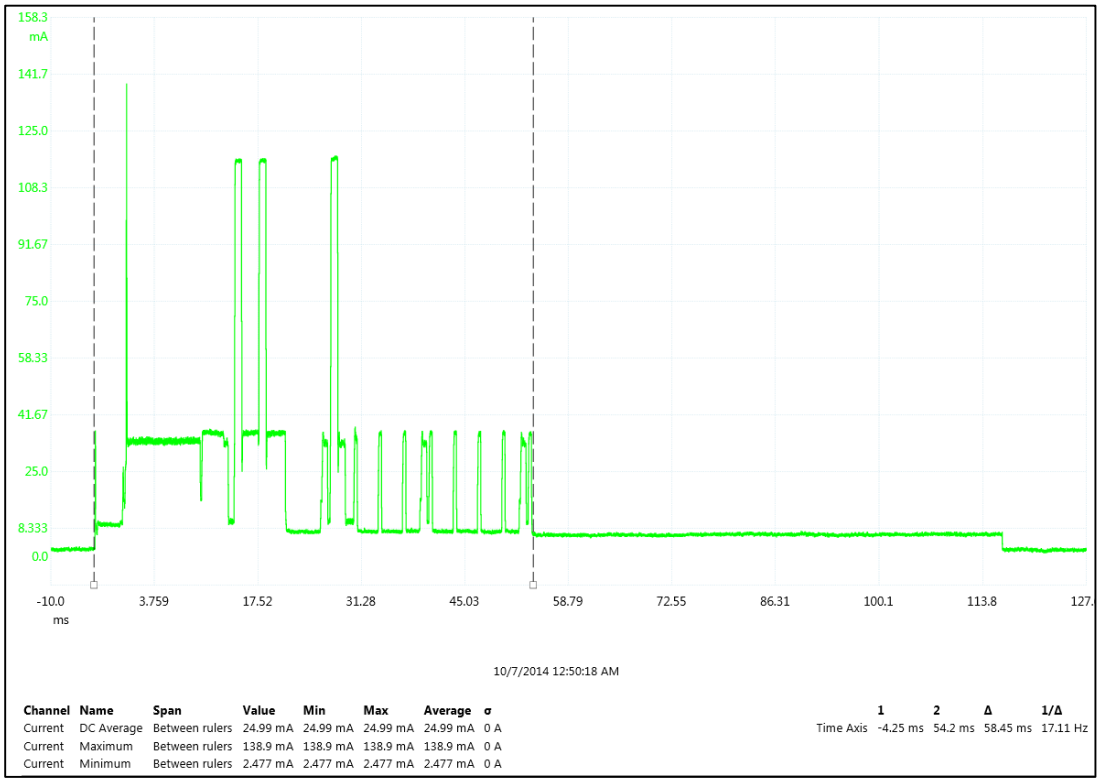

Figure 1: Typical 5 frame wake cycle current profile for 10 byte TX (RF frame = 3 slots, RF Packet Size = 0x0A - 0x25)

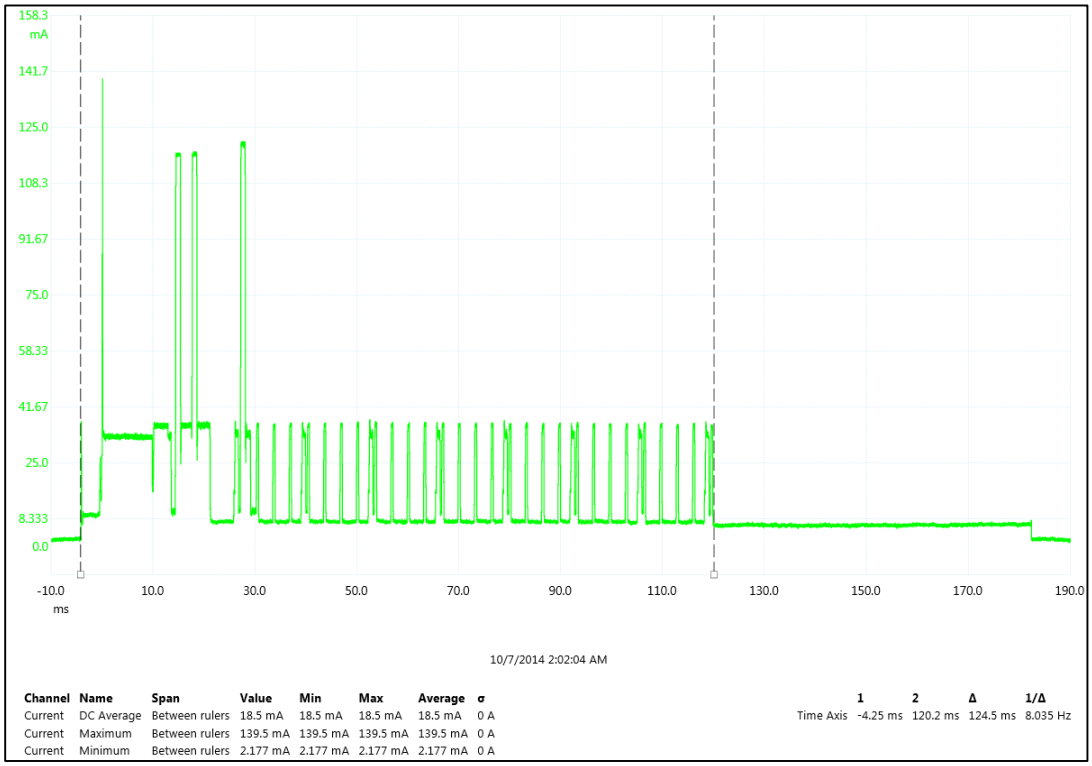

Figure 2: Typical 10 frame wake cycle current profile for 10 byte TX (RF frame = 3 slots, RF Packet Size = 0x0A - 0x25)

ADDITIONAL INFORMATION

Documentation, product information, and software downloads are available from the Embedded Wireless Solutions Support Center: https://laird-ews-support.desk.com/?b_id=1986

Product information can also be accessed from the RM024 product page on the Laird website: http://www.lairdtech.com/products/rm024

REVISION HISTORY

Revision	Date	Description	Initiated By
1.0	12 Jan 2015	Initial Release	Chris Downey