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# **[MG2470] Datasheet**

**(No. ADS0401)**

**V1.33**

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## REVISION HISTORY

Version	Date	Description
VER.1.0	2010.09.30	<ul style="list-style-type: none"> <li>▪ First official version 1.0 release</li> </ul>
VER.1.1	2010.11.05	<ul style="list-style-type: none"> <li>▪ Sec 7.2/7.3/7.4</li> <li>- Updated the interrupt &amp; MAC section</li> <li>- Removed the timer 2 &amp; 3 section</li> <li>- Changed name of some registers</li> </ul>
VER.1.2	2011.01.03	<ul style="list-style-type: none"> <li>▪ Removed the contents related to MG2470-B72 in all sections.</li> <li>▪ Sec 5.9</li> <li>- Updated the electrical characteristics of 16MHz RC Oscillator</li> <li>▪ Sec 6</li> <li>- Updated typical application circuit in Figure 3 / Table 2.</li> </ul>
VER.1.3	2011.4.5	<ul style="list-style-type: none"> <li>▪ Sec 4</li> <li>- Added the contents related to the TRSW/TRSWB</li> <li>▪ Sec 7.1.4</li> <li>- Table 3 is modified.</li> <li>- P1SRC_SEL contents added.</li> <li>- Power Control SFR contents added.</li> <li>▪ Sec 8.5</li> <li>- Renamed the WDT register to WDTCON register.</li> <li>▪ Sec 8.12</li> <li>- Figure 17 is modified.</li> <li>▪ Sec 9.2.8</li> <li>- Contents modified.</li> <li>- TXDA / P1SRC_SEL / MONCON1 registers are modified.</li> </ul>
VER.1.31	2011.4.20	<ul style="list-style-type: none"> <li>▪ Sec 9.2.2</li> <li>- Table 8 is modified</li> <li>▪ Sec 6</li> <li>- Figure 3 &amp; Table 2 are modified</li> </ul>
VER.1.32	2011.5.12	<ul style="list-style-type: none"> <li>▪ Sec 4</li> <li>- Added descriptions for RF_P, RF_N, P0[6]</li> <li>▪ Sec 5.2</li> <li>- Voltage on any digital pin is added.</li> <li>▪ Sec 6</li> <li>- Added description for RF_P &amp; RF_N bias condition.</li> <li>▪ Sec 10</li> <li>- Added notice for P0[6] in the ISP mode</li> </ul>
VER.1.33	2011.6.28	<ul style="list-style-type: none"> <li>▪ Sec 5.3</li> <li>- changed the values</li> </ul>

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## 1. INTRODUCTION

**MG2470** is a true 2.4 GHz system-on-chip (SOC) designed for low-power and low-cost applications based on IEEE802.15.4 and RF4CE. The MG2470 uses the ISM band of 2.4 ~ 2.48 GHz. In addition to the standard data-rate specified in IEEE802.15.4, enhanced multiple data-rate modes (31.25Kbps ~ 1Mbps) with channel coding are supported.

**MG2470** combines an advanced RF transceiver with an industry-standard enhanced 8051 MCU, a baseband PHY, a MAC with AES-128 HW engine, an in-system programmable 64KB flash memory, a 6-KB RAM, and many other application-specific peripherals. For voice applications, the voice encoder/decoder of ADPCM and  $\mu$ /a-law are embedded. This chip is best for very low-power RF4CE remote control applications.

### 1.1. APPLICATIONS

- 2.4 GHz IEEE 802.15.4 Applications
- RF4CE Remote Control Systems
- Lighting Systems
- Voice Applications
- Home/Building Automation
- Industrial Control and Monitoring
- Energy Management
- Low Power Wireless Sensor Networks
- Consumer Electronics
- Health-care equipments
- Toys

## 2. KEY FEATURES

### RF Transceiver

- Single-chip 2.4GHz RF Transceiver
- Low Power Consumption
- High Sensitivity of -99dBm at 250kbps
- No External T/R Switch or Filter needed
- On-chip VCO, LNA, and PA
- Programmable Output Power up to +9.6dBm
- Direct Sequence Spread Spectrum
- O-QPSK Modulation
- Scalable Data Rate including 250Kbps specified in IEEE802.15.4: 31.25Kbps ~ 1Mbps
- RSSI Measurement
- Compliant to IEEE802.15.4

### Hardwired MAC

- Two 256-byte circular FIFOs
- FIFO management
- AES Encryption/Decryption Engine(128 bit)
- CRC-16 Computation and Check

### 8051-Compatible MCU

- 8051 Compatible (single cycle execution)
- 64KB Embedded Flash Memory
- 6KB Data Memory
- 128-byte CPU dedicated Memory
- 1KB Boot ROM
- Dual DPTR Support
- I2S/PCM Interface with two 256-byte FIFOs
- $\mu$ -law/a-law/ADPCM Voice Encoder/Decoder
- Two High-Speed UARTs with Two 16-byte FIFOs(up to 1Mbps)
- Two Timer/Counters
- 5 PWM channels
- Watchdog Timer
- Sleep Timer using the 32kHz RC-OSC clock
- Quadrature Signal Decoder
- 22 General Purpose I/Os for MG2470-F48
- Internal 32kHz RC oscillator for Sleep Timer
- 16 MHz High Speed RC oscillator for the fast start-up from reset & power-down mode
- On-chip Power-on-Reset and Brown-out detector
- 4-channel 12-bit ADC( ENOB > 10-bit)
- SPI Master/Slave Interface with two 16-byte FIFOs
- I2C Master/Slave with 16-byte FIFO
- Programmable IR(Infra-Red) Modulator
- ISP (In System Programming)
- External clock output function(500KHz, 1/2/4/8/16/32 MHz selectable)



**Clock Inputs**

- 32MHz Crystal for System Clock

**Power**

- 1.8V(Core)/2.0~3.6V(I/O) Operation
- Power Management Scheme with Deep Sleep Mode
- Separate On-chip Regulators for Analog and Digital Circuitry.
- Power Supply Range for Internal Regulator(2.0V(Min) ~ 3.6V(Max))

**Package**

- Lead-Free 48-pin QFN Package (7mm x 7mm)

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### 3. BLOCK DIAGRAM

[Figure 1] shows the block diagram of MG2470. The MG2470 consists of a 2.4GHz RF, a baseband PHY, a MAC hardware engine, an industry-standard enhanced 8051 MCU, an in-system programmable flash memory 64KB, a 6KB data RAM, and rich peripherals such as a voice encoder/decoder block, I2C, 5-channel PWM.

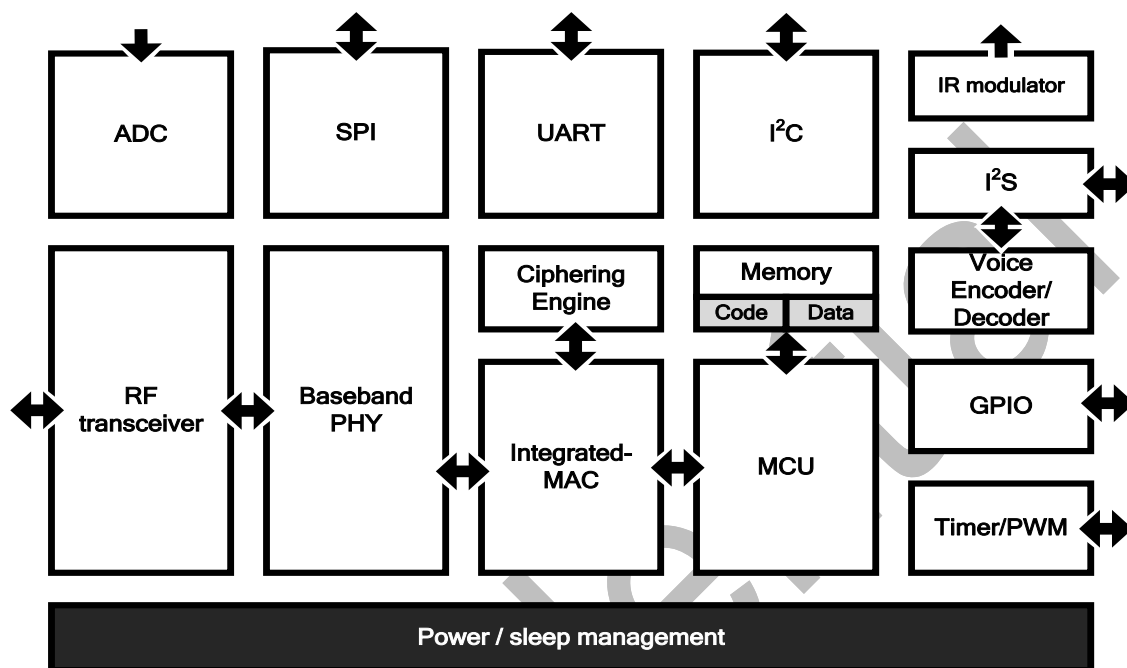


Figure 1. Functional Block Diagram of MG2470

MG2470 integrates an RF transceiver compliant to IEEE802.15.4 RF. The RF transceiver operates on an ISM band of 2.4 ~ 2.48GHz with excellent receiver sensitivity and programmable output power up to +9.6dBm. See Sec 9.3 for the detailed explanation for the RF transceiver.

The MAC block supports IEEE802.15.4 compliant functions and it is located between the microprocessor and the baseband modem. MAC block includes FIFOs for transmitting/receiving packets, an AES engine for security operation, a CRC and related control circuit. In addition, it supports automatic CRC check and address decoding.

MG2470 integrates a high performance embedded microcontroller, compatible to an Intel 8051 microcontroller in an instruction level. This embedded microcontroller has 8-bit operation architecture sufficient for controller applications. The embedded microcontroller has 4-stage pipeline architecture to improve the performance over previous compatible chips making it capable of executing simple instructions during a single cycle.

The memory part of the embedded microcontroller consists of program memory and data memory. The data memory has 2 memory areas. For more detailed explanations, refer to Sec 7.1.2. Data Memory.

MG2470 includes 22 GPIOs for MG2470-F48 and various peripheral circuits to aid in the

development of the application circuit with an interrupt handler to control the peripherals. MG2470 uses 32MHz crystal oscillator for RF PLL and 8MHz clock generated from 32MHz in clock generator is used as the default clock of 8051 MCU subsystem. The MAC and clocks of the baseband modem are separately controlled by the system clock and reset module.

MG2470 supports a voice function as follows. The data generated by an external ADC is inputted to the voice block via I2S interface. After the data is received via I2S, it is compressed by the voice encoder and stored in the Voice TXFIFO. Then the data in the Voice TXFIFO is transferred to the MAC TXFIFO and transmitted via PHY. On the other hand, the received data in the MAC RXFIFO is transferred to voice RXFIFO via DMA operation. Then the data in the Voice RXFIFO is decompressed in the internal voice decoder. After that, the decompressed data is transferred to the external DAC via I2S interface.

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### 4. PIN DESCRIPTION

The pin-out diagram of MG2470-F48 is shown in [Figure 2]. The description for that is summarized in [Table 1].

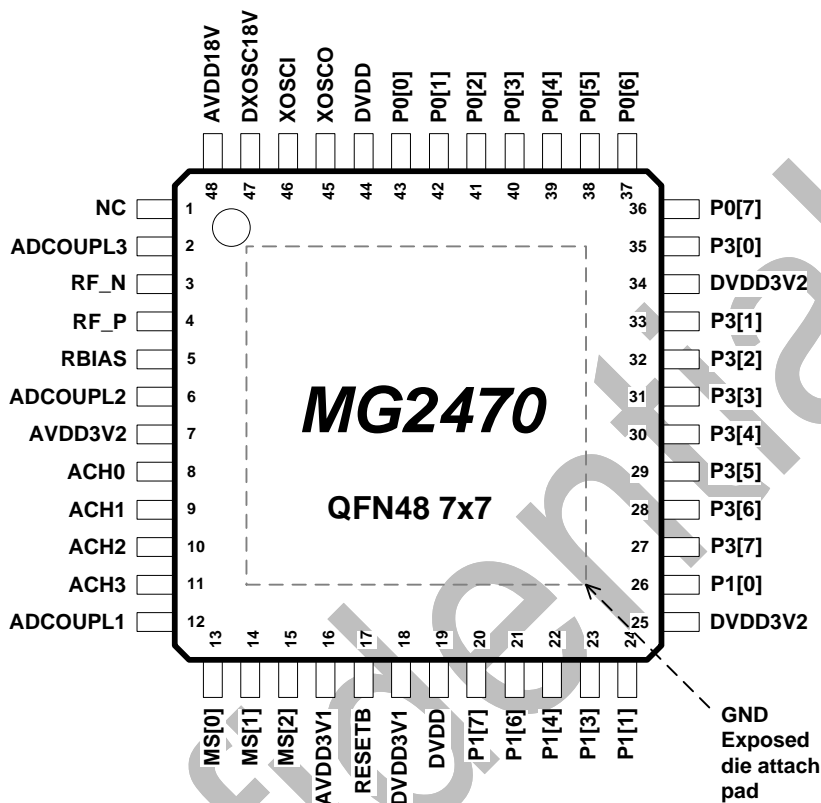


Figure 2. Pinout Top View of MG2470-F48

Note: The exposed ground pad is located at the bottom of the chip and electrically connected to the die ground inside the package. It must be connected to a solid ground plane.

Table 1. Pin Description

Radio, Synthesizer, and Oscillator			
Name	QFN Pin	Type	Description
AVDD3V1	16	Power	2.0V to 3.6V RF/Analog power supply connection
AVDD3V2	7	Power	2.0V to 3.6V RF/Analog power supply connection
ADCOUPL1	12	Power	1.8V RF/Analog power supply decoupling. Do not use for supplying external circuits.
ADCOUPL2	6	Power	1.8V RF/Analog power supply decoupling. Do not use for supplying external circuits.
ADCOUPL3	2	Power	1.8V RF/Analog power supply decoupling. Do not use for supplying external circuits.
AVDD18V	48	Power	1.8V RF/Analog power supply connection
RF_P	4	RF I/O	Positive RF input signal to LNA in RX mode Positive RF output signal from PA in TX mode It should be biased by ADCOUP3. Refer to Figure 3 (Sec.6).
RF_N	3	RF I/O	Negative RF input signal to LNA in RX mode

			Negative RF output signal from PA in TX mode It should be biased by ADCOUP3. Refer to Figure 3 (Sec.6).										
RBIAS	5	Analog I/O	External precision bias resistor(510kohm) to generate the reference current										
ACH0	8	Analog I/O	ADC input										
ACH1	9	Analog I/O	ADC input										
ACH2	10	Analog I/O	ADC input										
ACH3	11	Analog I/O	ADC input										
<b>Digital and Oscillator</b>													
<b>Name</b>	<b>Pin</b>	<b>Type</b>	<b>Description</b>										
DVDD3V1	18	Power	2.0V to 3.6V Digital power supply connection										
DVDD3V2	25,34	Power	2.0V to 3.6V Digital power supply connection										
DVDD	19,44	Power	1.8V Digital power supply decoupling. Do not use for supplying external circuits.										
DXOSC18V	47	Power	1.8V Digital power supply connection										
RESETB	17	Digital input	Reset, active low										
MS[0]	13	Digital input	Mode Selection <table border="1"> <thead> <tr> <th>Value</th> <th>Mode Configuration</th> </tr> </thead> <tbody> <tr> <td>000</td> <td>Normal mode with internal digital regulator</td> </tr> <tr> <td>010</td> <td>Normal mode with external digital regulator</td> </tr> <tr> <td>100</td> <td>ISP mode with internal digital regulator</td> </tr> <tr> <td>110</td> <td>ISP mode with external digital regulator</td> </tr> </tbody> </table>	Value	Mode Configuration	000	Normal mode with internal digital regulator	010	Normal mode with external digital regulator	100	ISP mode with internal digital regulator	110	ISP mode with external digital regulator
Value	Mode Configuration												
000	Normal mode with internal digital regulator												
010	Normal mode with external digital regulator												
100	ISP mode with internal digital regulator												
110	ISP mode with external digital regulator												
MS[1]	14	Digital input											
MS[2]	15	Digital input											
P0[0]	43	Digital I/O	Port P0.0/I2SRX_DI/PWM0, 16mA drive capability										
P0[1]	42	Digital I/O	Port P0.1/I2SRX_LRCLK/PWM1, 16mA drive capability										
P0[2]	41	Digital I/O	Port P0.2/I2SRX_BCLK/PWM2, 16mA drive capability										
P0[3]	40	Digital I/O	Port P0.3/I2SRX_MCLK/PWM3, 16mA drive capability										
P0[4]	39	Digital I/O	Port P0.4/I2STX_DO/PWM4, 16mA drive capability										
P0[5]	38	Digital I/O	Port P0.5/I2STX_LRCLK/PTC_GATE0										
P0[6]	37	Digital I/O	Port P0.6/I2STX_BCLK/PTC_GATE1 <b>*Notice : This pin should not be set to 0 under the ISP mode.</b>										
P0[7]	36	Digital I/O	Port P0.7/I2STX_MCLK/PTC_GATE2										

P1[0]	26	Digital I/O	Port P1.0/RXD1
P1[1]	24	Digital I/O	Port P1.1/TXD1
P1[3]	23	Digital I/O	Port P1.3/QUADZA/PTC_GATE3/IR_TX/CLK_OUT
P1[4]	22	Digital I/O	Port P1.4/QUADZB/EXT_RTC_CLK/PTC_GATE4
P1[6]	21	Digital I/O	Port P1.6/I2C_SCL/TRSWB
P1[7]	20	Digital I/O	Port P1.7/I2C_SDA/TRSW
P3[0]	35	Digital I/O	Port P3.0/RXD0/QUADXA
P3[1]	33	Digital I/O	Port P3.1/TXD0/QUADXB
P3[2]	32	Digital I/O	Port P3.2/nINT0
P3[3]	31	Digital I/O	Port P3.3/nINT1
P3[4]	30	Digital I/O	Port P3.4/RTS0/QUADYA/SPIDI/T0
P3[5]	29	Digital I/O	Port P3.5/CTS0/QUADYB/SPIDO/T1
P3[6]	28	Digital I/O	Port P3.6/RTS1/SPICLK
P3[7]	27	Digital I/O	Port P3.7/CTS1/SPICSN
XOSCI	46	Analog I/O	32MHz crystal oscillator pin
XOSCO	45	Analog I/O	32MHz crystal oscillator pin or external clock input
NC	1		Do not connect.
<b>Ground (MG2470-F48)</b>			
Exposed bottom		Ground	Ground for RF, Analog, digital core, and I/O

## 5. ELECTRICAL CHARACTERISTICS

### 5.1. Absolute Maximum Ratings

Parameter	Min.	Max	Unit	
Supply Voltage(AVDD3V1,AVDD3V2 ,DVDD3V1,DVDD3V2)	-0.3	3.6	V	All supply pins must have the same voltage.
Core voltage(ADCOUPL1,ADCOUPL2,ADCOUPL3,AVDD18V,DVDD,DXOSC18V)	-0.3	2	V	
Storage Temperature	-40	85	°C	
ESD	HBM	2	kV	All pads, according to human-body model(JEDEC STD 22)
	CDM	500	V	According to charged-device model(JEDEC STD 22)

Exceeding one or more of these ratings may cause permanent damage to the device. These are stress ratings only, and the functional operation of the device at these or any other conditions beyond those indicated under “ELECTRICAL SPECIFICATIONS” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

**NOTE1:** These values were obtained under worst-case test conditions specially prepared for the MG2470 and these conditions are not sustained in normal operation environment.

**CAUTION:** ESD sensitive device. Precaution should be used when handling the device to prevent permanent damage.

### 5.2. Recommended Operating Conditions

Parameter	MIN	MAX	UNIT
Operating ambient temperature range, T <sub>OP</sub>	-40	85	°C
Operating supply voltage, VDD (AVDD3V1,AVDD3V2,DVDD3V1,DVDD3V2)	2	3.6	V
Voltage on any digital pin	-0.3	VDD	V

### 5.3. DC Characteristics

T<sub>OP</sub>=25°C, VDD=3.0V, unless otherwise stated.

Parameter	Name	MIN	TYP	MAX	UNIT
Logic-low input voltage		-0.3		0.8	V
Logic-high input voltage		2		VDD	V
I/O-pin pull-up and pull-down resistors			48		kΩ
Logic-low output voltage				0.4	V
Logic-high output voltage		2.4			V

**NOTE 1:** All voltage values are based on Ground. All input and output voltage levels are TTL-compatible.

## 5.4. Current Consumption and timing characteristics

$T_{OP} = 25^{\circ}\text{C}$ ,  $V_{DD}=3.0\text{V}$ , unless otherwise noted.

Parameter(Condition)	MIN	TYP	MAX	UNIT
MCU active. No radio and peripherals (UART1&RNG) active. @ MCU clock = 8MHz		4.2		mA
RX mode , MCU active and peripherals (UART1&RNG) active		25		mA
TX mode , MCU active and peripherals (UART1&RNG) active @maximum output power @+0dBm		43 25		mA
Power mode1. Digital regulator on, 16MHz RCOSC and 32MHz crystal oscillator off, 32kHz RCOSC, POR, BOD, and sleep timer active.		66		$\mu\text{A}$
Power mode1. Digital regulator on, 16MHz RCOSC, 32MHz crystal oscillator, and BOD off, 32kHz RCOSC, POR, and sleep timer active.		30	50	$\mu\text{A}$
Power mode2. Digital regulator off, 16MHz RCOSC, 32MHz crystal oscillator off, 32kHz RCOSC and sleep timer active.		1.25	2	$\mu\text{A}$
Power mode3. Digital regulator off, 16MHz RCOSC, 32MHz crystal oscillator off, 32kHz RCOSC and sleep timer off.		0.1	1	$\mu\text{A}$
<b>Wake-up and timing</b>				
Power mode1 → MCU Active Digital regulator on, 16MHz RCOSC and 32MHz crystal oscillator off. Start-up of 16MHz RCOSC		5		$\mu\text{s}$
Power mode2 → MCU Active Digital regulator off, 16MHz RCOSC and 32MHz crystal oscillator off. Start-up of regulator and 16MHz RCOSC		100		$\mu\text{s}$
MCU Active → TX or RX Initially running on 16MHz RCOSC, Added start-up time of 32MHz crystal oscillator.		992		$\mu\text{s}$
TX/RX and RX/TX turnaround			192	$\mu\text{s}$

## 5.5. RF Receive Section

Measured on 4-layer reference design with  $T_{OP}=25^{\circ}\text{C}$ ,  $V_{DD}=3.0\text{V}$ , and  $f_c=2450\text{MHz}$ , unless otherwise noted.

Parameter(Condition)	MIN	TYP	MAX	UNIT
RF frequency range	2394		2507	MHz
Maximum input level (PER=1%) @ 1000kbps @ 500kbps @ 250kbps @ 125kbps @ 62.5kbps @ 31.25kbps		-11 -12 -9 -9 -6 -4		dBm
Spurious radiation @30MHz-1000MHz @1GHz-12.75GHz		-73.7 -73.7		dBm
Received RF bandwidth		2		MHz
Channel bandwidth		5		MHz
Receiver sensitivity (PER $\leq$ 1%, packet length of 22-byte) @ 1000kbps @ 500kbps @ 250kbps		-93 -94 -99		dBm



@ 125kbps @ 62.5kbps @ 31.25kbps		-100 -103 -105		
Adjacent channel rejection (Sensitivity+3, adjacent modulated channel at $\pm 5$ MHz, PER=1%, 250kbps) +5MHz -5MHz		30 30		dB
Alternate channel rejection (Sensitivity+3, adjacent modulated channel at $\pm 10$ MHz, PER=1%, 250kbps) +10MHz -10MHz		50 50		dB
Others channel rejection (Sensitivity+3, adjacent modulated channel at over $\pm 15$ MHz, PER=1%, 250kbps) $\geq +15$ MHz $\geq -15$ MHz		52 54		dB
Co-channel rejection (Sensitivity+3. Undesired IEEE 802.15.4 modulated signal at the same frequency. Signal level for PER=1%, 250kbps)		-5.9		dB
Blocking/desensitization +5MHz -5MHz +10MHz -10MHz +20MHz -20MHz +30MHz -30MHz +50MHz -50MHz		-53 -52 -48 -46 -44 -40 -43 -38 -41 -37		dBm
RSSI dynamic range		80		dB
RSSI accuracy		$\pm 3$		dB

## 5.6. RF Transmit Section

Measured on 4-layer reference design with  $T_{OP}=25^{\circ}\text{C}$ ,  $V_{DD}=3.0\text{V}$ , and  $f_c=2450\text{MHz}$ , unless otherwise noted.

Parameter(Condition)	MIN	TYP	MAX	UNIT
RF frequency range	2394		2507	MHz
TX output power (using the recommended matching circuit)			9.6	dBm
Transmit chip rate		2		Mcps
Error vector magnitude(EVM)		6.5		%
Harmonics 2 <sup>nd</sup> harmonic 3 <sup>rd</sup> harmonic		-42.5 -77.7		dBm
Spurious emission (complies with EN 300-440, FCC and ARIB STD-T66) 30Hz ~ 1GHz 1GHz ~ 12.75GHz 5.15GHZ ~ 5.3GHZ		< -63.1 < -42.5 < -69.1		dBm

## 5.7. Frequency Synthesizer

$T_{OP}=25^{\circ}\text{C}$ ,  $V_{DD}=3.0\text{V}$ , and  $f_c=2450\text{MHz}$ , unless otherwise noted.

Parameter(Condition)	MIN	TYP	MAX	UNIT
Phase noise, unmodulated carrier				
@ $\pm 100\text{kHz}$ offset		-79.9		dBc/Hz
@ $\pm 1\text{MHz}$ offset		-104.2		
@ $\pm 2\text{MHz}$ offset		-111.0		
@ $\pm 3\text{MHz}$ offset		-113.8		
@ $\pm 5\text{MHz}$ offset		-115.6		
Lock time			192	$\mu\text{s}$

## 5.8. 32MHz Crystal Oscillator

$T_{OP}=25^{\circ}\text{C}$ ,  $DXOSC18V=1.8\text{V}$ , unless otherwise noted.

Parameter(Condition)	MIN	TYP	MAX	UNIT
Crystal frequency		32		MHz
Crystal frequency accuracy requirement	-40		40	ppm
Equivalent series resistance(ESR)			60	$\Omega$
Crystal shunt capacitance( $C_O$ )			5	pF
Crystal load capacitance( $C_L$ )			16	pF
Start-up time			0.8	ms

## 5.9. 16MHz RC Oscillator

$T_{OP}=25^{\circ}\text{C}$ ,  $DXOSC18V=1.8\text{V}$ , unless otherwise noted.

Parameter(Condition)	MIN	TYP	MAX	UNIT
Frequency		16		MHz
Frequency accuracy before calibration	-25		25	%
Frequency accuracy after calibration	-3		3	%
Initial calibration time		50		$\mu\text{s}$
Start-up time			1	$\mu\text{s}$

## 5.10. 32kHz RC Oscillator

$T_{OP}=25^{\circ}\text{C}$ ,  $V_{DD}=3.0\text{V}$ , unless otherwise noted.

Parameter(Condition)	MIN	TYP	MAX	UNIT
Calibrated frequency		32.787		kHz
frequency accuracy after calibration	-0.3		0.3	%
Initial calibration time		1		ms
Start-up time			100	$\mu\text{s}$

## 5.11. Temperature Sensor

VDD=3.0V, unless otherwise noted.

Parameter(Condition)	MIN	TYP	MAX	UNIT
output voltage at -40°C		716		mV
output voltage at 0°C		847		mV
output voltage at 40°C		978		mV
output voltage at 80°C		1109		mV
temperature coefficient		3.275		mV/°C

All measurement results are obtained using the 12bit ADC.

## 5.12. ADC

T<sub>OP</sub>=25°C, VDD=3.0V, unless otherwise noted.

Parameter(Condition)	MIN	TYP	MAX	UNIT
Input voltage	0		VDD	V
Input resistance		150		kΩ
Full-scale signal			3	V
Effective number of bits(ENOB) Single-ended input, 12bit setting		10.8		bits
Signal to noise and distortion(SINAD) Single-ended input, 12bit setting		66.78		dB
Current consumption		0.62		mA
Internal reference voltage		1.25		V

## 5.13. Flash Memory

### 5.13.1. Flash memory characteristics

Characteristic	Symbol	Conditions	MIN	TYP	MAX	UNIT
Endurance	Nendu	20ms erase and 20 us program time at 1.8V	20,000			cycles
Data retention	Tret	25 °C	100			years

### 5.13.2. Flash memory and page size

Name	Size	Unit
Flash main memory block	65536	bytes
Flash information block	1024	bytes
Flash page size	512	bytes

## 6. REFERENCE APPLICATION CIRCUITS

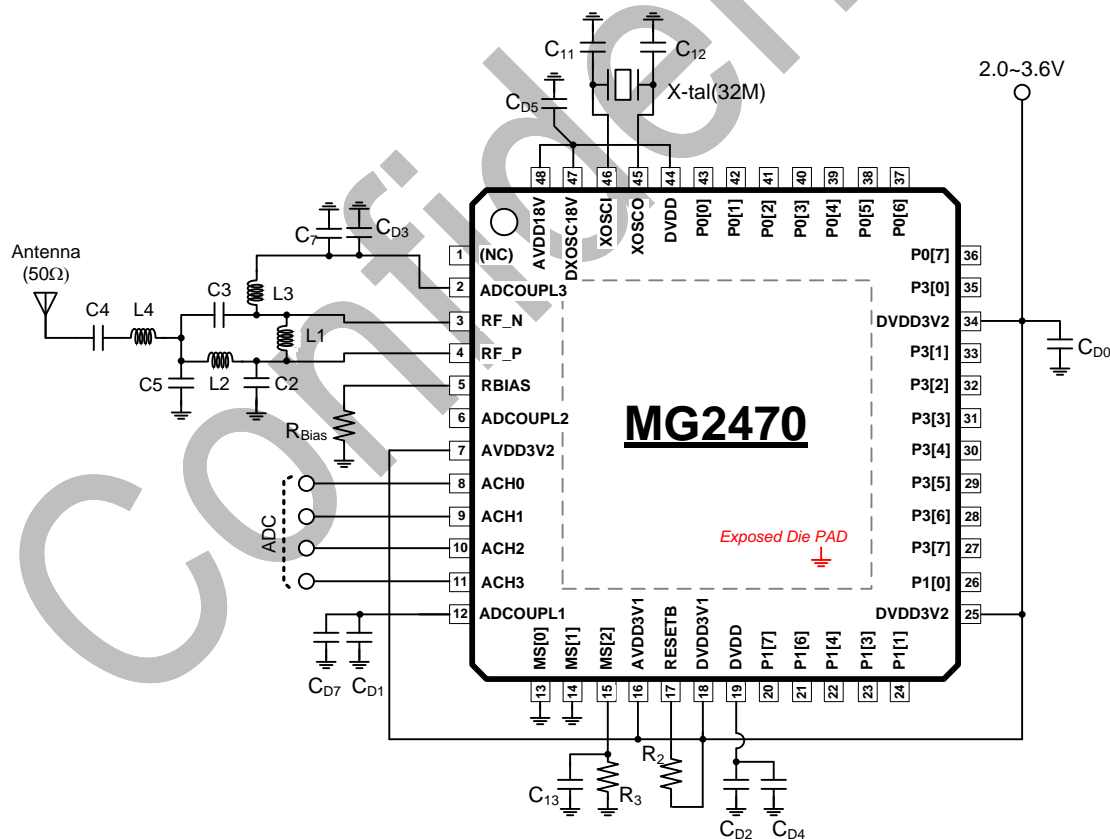
A typical application diagram of the MG2470 is shown in [Figure 3]. Only a few external components are required for the operation of the MG2470. [Table 2] describes the external components including decoupling capacitors.

The inductor, L1 is used as a matching component for the LNA and as an output load for the PA, respectively. The components near the RF\_P/RF\_N pins, L2, L3, C2, and C3 form a balun which converts the differential RF signals to a single-ended RF signal. And, L4, C4, and C5 form a LC harmonic filter to suppress the TX output harmonics. In addition, C4 is needed for DC blocking. All together with adequate values, they also transform the impedance to match a 50-Ohm antenna.

As shown in [Figure 3], RF\_P and RF\_N are biased by ADCOUP3 through L1 and L3.

The 32MHz crystal provides the reference frequency source for MG2470. C11 and C12 are loading capacitors of it. CD0, CD1, CD2 CD3, CD4, CD5, CD7, and C7 are supply decoupling capacitors, whose values depend on PCB artwork and stack-up information.

The components' values listed in Table 2 are selected for 4-layer reference PCB design.



\*\*\* GND is bottom pad (down-bonding pad) in the above schematic  
**Figure 3. MG2470 Typical Application Circuit**

**Table 2. Bill of Materials for Figure 3**

No	Component	Description	Value
1	L1	RF matching inductor	3.3nH
2	L2, L3	RF balun inductors	5.6nH
3	C2, C3	RF balun capacitors	0.75pF
4	L4	RF LC filter/matching inductor	3.9nH
5	C5	RF LC filter/matching capacitor	1.1pF
6	C4	RF matching/DC blocking capacitor	1.8pF
7	Rbias	Resistor for internal bias current reference	510kohm
8	X-tal	32MHz crystal unit	32MHz
9	C11, C12	Crystal loading capacitors	30pF
10	C <sub>D0</sub>	Decoupling capacitor for DVDD3V	10uF
11	C <sub>D1</sub>	Decoupling capacitor for ADCOUP1	1uF
12	C <sub>D7</sub>	Decoupling capacitor for ADCOUP1	1uF
13	C <sub>D3</sub>	Decoupling capacitor for ADCOUP3	1uF
14	C7	Decoupling capacitor for ADCOUP3	6pF
15	C <sub>D2</sub>	Decoupling capacitor for DVDD	1uF
16	C <sub>D4</sub>	Decoupling capacitor for DVDD	1uF
17	C <sub>D5</sub>	Decoupling capacitor for DVDD and DXOSC18V	100pF
18	R <sub>2</sub>	Pull-up resistor for RESETB input	82kohm
19	R <sub>3</sub>	Pull-down resistor for MS[2] input	10kohm
20	C <sub>13</sub>	Capacitor for MS[2] input	1uF

## 7. MCU SUBSYSTEM

### 7.1. Memory Organization

#### 7.1.1. Program Memory

The address space of program memory is 64KB (0x0000~0xFFFF). Basically, the lower 63KB of program memory is implemented by Non-volatile memory. The upper 1KB from 0xFC00 to 0xFFFF is implemented by both Non-volatile memory and ROM. As shown in [Figure 4] below, there are two types of memory in the same address space. The address space, which is implemented by Non-volatile memory, is used as general program memory and the address space, which is implemented by ROM, is used for ISP (In-System Programming).

As shown in (a) of [Figure 4] below, when Power is turned on, the upper 1KB of program memory is mapped to ROM under the ISP mode. As shown in (b) of [Figure 4], this program area (1KB) is used as non-volatile program memory under the normal mode. The ROM area can't be accessed under the normal mode. If necessary, the ROM access is possible by setting the SFR for ENROM. Please see to Sec 7.1.4. WCON SFR for ENROM for details.

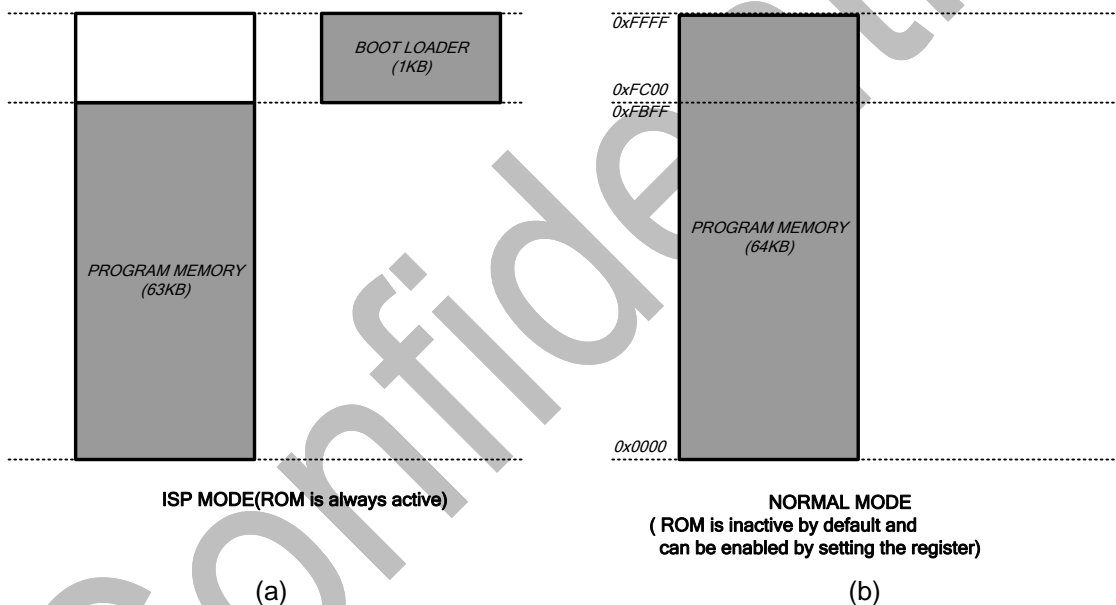


Figure 4. Address Map of Program Memory

### 7.1.2. Data Memory

MG2470 reserves 64 KB data memory address space. This address space can be accessed by MOVX instruction. [Figure 5] shows the address map of MG2470 data memory.

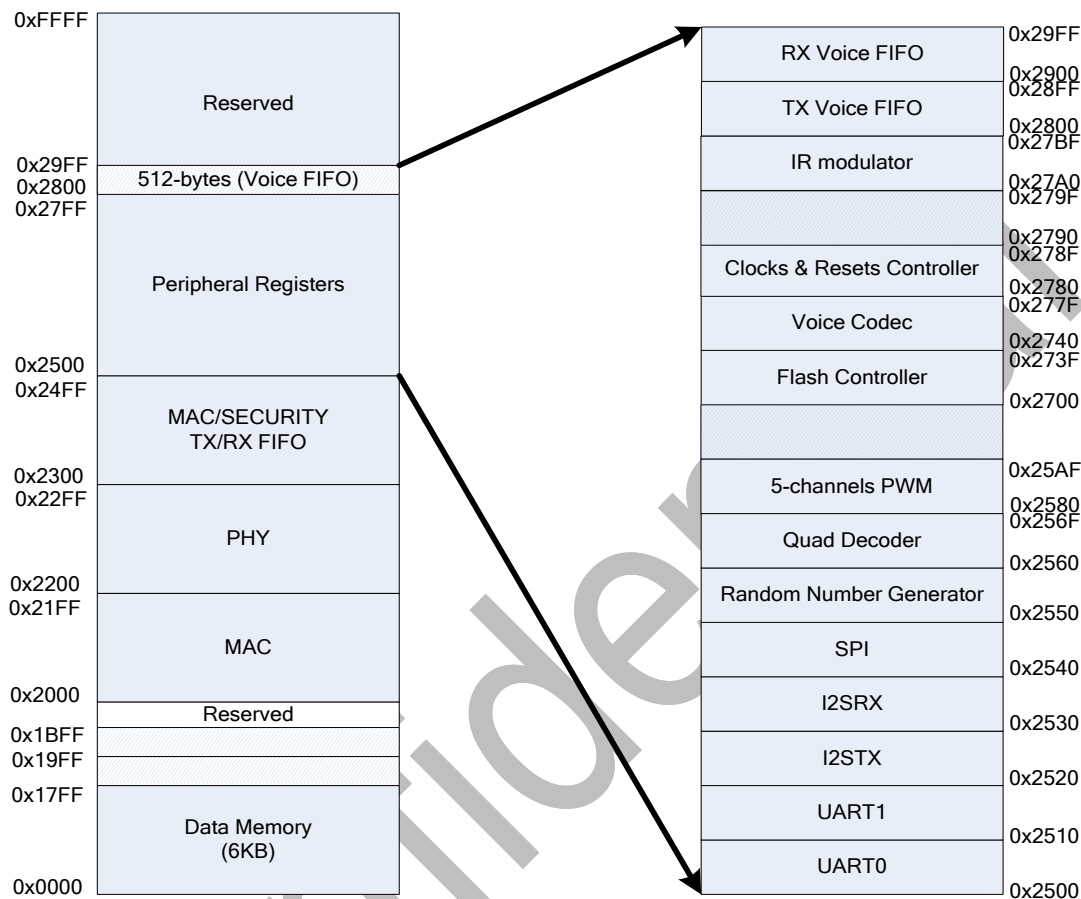


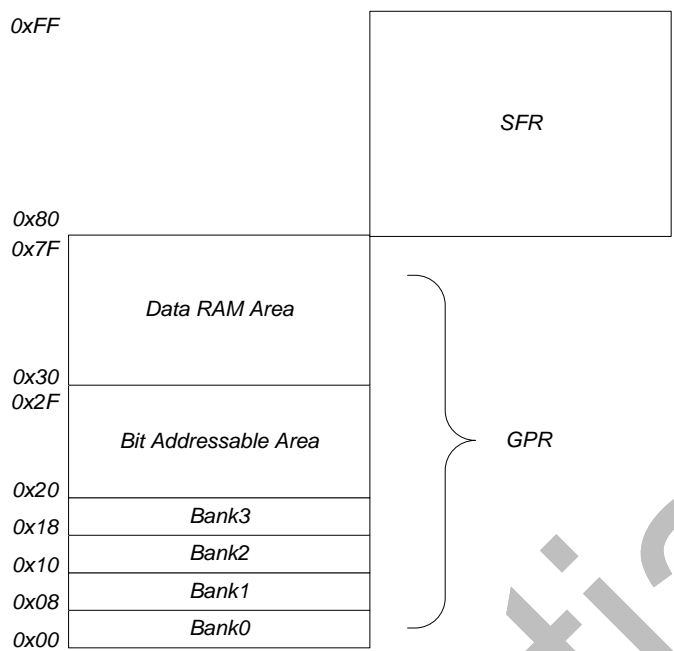
Figure 5. Address Map of Data Memory

The data memory used in the application programs resides in the address range 0x0000-0x17FF. The registers and memory used in the MAC block reside in the address range 0x2000-0x21FF and 0x2300-0x24FF respectively. The registers to control or report the status of PHY block reside in the address range 0x2200-0x22FF. Registers related to the numerous peripheral functions of the embedded microprocessor reside in the address range of 0x2500-0x29FF.

### 7.1.3. General Purpose Registers

[Figure 6] describes the address map of the General Purpose Registers (GPRs). GPRs can be addressed either directly or indirectly. As shown in the lower address space of [Figure 6], a bank consists of 8 registers.

The address space above the bank area is the bit addressable area, which is used as a flag by software or by a bit operation. The address space above the bit addressable area includes registers used as a general purpose of a byte unit. For more detailed information, refer to the paragraphs following [Figure 6] below.



**Figure 6. GPRs Address Map**

**Register Bank 0-3:** It is located from 0x00 to 0x1F (32 bytes). One bank consists of each 8 registers out of 32 registers. Therefore, there are total 4 banks. Each bank should be selected by software as referring the RS field in PSW register. The bank (8 registers) selected by RS value can be accessed by a name (R0-R7) by software. After reset, the default value is set to bank0.

**Bit Addressable Area:** The address is assigned to each bit of 16 bytes (0x20~0x2F) and registers, which is the multiple of 8, in SFR. Each bit can be accessed by the address which is assigned to these bits. 128 bits (16 bytes, 0x20~0x2F) can be accessed by direct addressing for each bit (0x00~0x7F address is assigned) and by a byte unit as using the address from 0x20~0x2F.

Data RAM Area: A user can use the data memory area (0x30~0x7F) as a general purpose.

**7.1.4. Special Function Registers(SFR)**

The special function registers (SFRs) reside in their associated peripherals or in the 8051 core.

The SFR include the status or control register of the I/O ports, the timer registers, the stack pointers and so on. [Table 3] shows the address to all SFRs in MG2470. Unoccupied locations in the SFR space (the blank locations in Table 3) are unimplemented, i.e., no register exists.

If an instruction attempts to write to an unimplemented SFR location, the instruction executes, but nothing is actually written. If an unimplemented SFR location is read, it returns a zero value.

All SFRs are accessed by a byte unit. However, when SFR address is multiple of 8, it can be accessed by a bit unit.



Table 3. SFR (Special Function Register) Memory Map

SFR Address	8 bytes								SFR Address
80	P0	SP	DPL	DPH				PCON	87
88	TCON	TMOD	TL0	TL1	TH0	TH1	CLKCON 1	CLKCON 2	8F
90	P1	EXIF1							97
98	PERI_CLK_STP0	PERI_CLK_STP1	PERI_CLK_STP2		P1SRC_SEL				9F
A0			AUXR1						A7
A8	IE								AF
B0	P3	P0OEN	P1OEN		P3OEN				B7
B8	IP	P0_IE	P1_IE		P3_IE				BF
C0	WCON	P0_DS	P1_DS		P3_DS				C7
C8									CF
D0	PSW		WDTCON						D7
D8	EXIF2								DF
E0	ACC								E7
E8	EIE1	EIE2							EF
F0	B								F7
F8	EIP2	EIP2							FF

The following section describes each SFR relating to microprocessor.

**Note 1: This table shows register bit symbol conventions.**

Symbol	Access Mode
RW	Read/write
RO	Read Only
WO	Write Only

### WCON (WRITE CONTROL REGISTER, 0xC0)

This register can control the upper 1KB of program memory.

Bit	Name	Descriptions	R/W	Reset Value
7:3		Reserved		0
2	ISPMODE	ISP Mode Indication. When MS[2:0], an external pin, is '100b', this field is set to 1 by hardware. It notifies the MCU whether ISPMODE or not.	RO	-
1	ENROM	When this field is '1', the upper 1KB (0xFC00~0xFFFF) is mapped to ROM. When this field is '0', the upper 1KB (0xFC00~0xFFFF) is mapped to non-volatile memory. The bit setting is effective under the normal mode. In the ISP mode, the ROM is always mapped to address range of 0xFC00~0xFFFF.	R/W	0
0		Reserved		0

**ACCUMULATOR (A or ACC, 0xE0)**

This register is marked as A or ACC and it is related to all the operations.

Bit	Name	Descriptions	R/W	Reset Value
7:0	A	Accumulator	R/W	0x00

**B REGISTER (B, 0xF0)**

This register is used for a special purpose when multiplication and division are processed. For other instructions, it can be used as a general-purpose register. After multiplication is processed, this register contains the MSB data and 'A register' contains LSB data for the multiplication result. In division operation, this register stores the value before division (dividend) and the remainder after division. At this time, before division, the divisor should be stored in 'A register' and result value (quotient) is stored in it after division.

Bit	Name	Descriptions	R/W	Reset Value
7:0	B	B register. Used in MUL/DIV instructions.	R/W	0x00

**PROGRAM STATUS WORD (PSW, 0xD0)**

This register stores the status of the program. The explanation of each bit is as follows.

Bit Field	Name	Descriptions	R/W	Reset Value
7	CY	Carry flag	R/W	0
6	AC	Auxiliary carry flag	R/W	0
5	F0	Flag0. User-defined	R/W	0
4:3	RS	Register bank select. 0: Bank0 1: Bank1 2: Bank2 3: Bank3	R/W	0
2	OV	Overflow flag	R/W	0
1	F1	Flag1. User-defined	R/W	0
0	P	Parity flag. Set to 1 when the value in accumulator has odd number of '1' bits.	R/W	0

**STACK POINTER (SP, 0x81)**

When PUSH and CALL instructions are executed, some data (like the parameters by function call) are stored in stack to inform the values. In embedded MCU, the data memory area which can be used for a general purpose (0x08~0x7F) is used as a stack area.

This register value is increased before the data is stored and decreased after the data is read when the POP and RET instructions are executed. The default value is 0x07.

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	SP	Stack Pointer	R/W	0x07

**DATA POINTER (DPH : 0x83, DPL : 0x82)**

Data pointer consists of a high byte (DPH) and a low byte (DPL) to support 16-bit address. It can be accessed by 16-bit register or by two 8-bit registers respectively.

Bit Field	Name	Descriptions	RW	Reset Value
7:0	DPH	Data pointer, high byte	R/W	0x00

Bit Field	Name	Descriptions	RW	Reset Value
7:0	DPL	Data pointer, low byte	R/W	0x00

### AUXILIARY CONTROL REGISTER (AUXR1, 0xA2)

This register is used to implement the Dual DPTR functions. Physically, The DPTR consists of DPTR0 and DPTR1. However, DPTR0 and DPTR1 can be accessed depending on the DPS value of AUXR1 respectively. In other words, they cannot be accessed at the same time.

Bit Field	Name	Descriptions	RW	Reset Value
7:1		Reserved		0x00
0	DPS	Dual DPTR Select: Used to select either DPTR0 or DPTR1. When DPS is '0', DPTR0 is selected. When DPS is '1', DPTR1 is selected.	R/W	0

### GPIO SFRs

Please refer to Sec 8.2. GPIO for more details. For P1SRC\_SEL, please refer to Sec 9.2.8.

Register	Address	Description
P0	0x80	PORT-0 data register
P1	0x90	PORT-1 data register
P1SRC_SEL	0x9C	PORT-1 source control register
P3	0xB0	PORT-3 data register
P0OEN	0xB1	PORT-0 direction register
P1OEN	0xB2	PORT-1 direction register
P3OEN	0xB4	PORT-3 direction register
P0_IE	0xB9	PORT-0 input enable register
P1_IE	0xBA	PORT-1 input enable register
P3_IE	0xBC	PORT-3 input enable register
P0_DS	0xC1	PORT-0 drive strength selection register
P1_DS	0xC2	PORT-1 drive strength selection register
P3_DS	0xC4	PORT-3 drive strength selection register

### WDT (WATCHDOG TIMER) SFR

Please refer to Sec 8.6. WDT for the more details.

Register	Address	Description
WDTCON	0xD2	Watchdog timer control register

### Timer 0/1 SFRs

Please refer to Sec 8.3. timer 0/1 for the more details.

Register	Address	Description
TCON	0x88	Timer/Counter 0 & 1 control
TMOD	0x89	Timer/Counter 0 & 1 mode control
TL0	0x8A	Timer/Counter 0 low byte
TH0	0x8C	Timer/Counter 0 high byte
TL1	0x8B	Timer/Counter 1 low byte

TH1	0x8D	Timer/Counter 1 high byte
-----	------	---------------------------

### 8051 MCU Clock Control SFRs

Please refer to Sec 7.2. clock for the more details.

Register	Address	Description
CLKCON1	0x8E	MCU subsystem reference clock control 1
CLKCON2	0x8F	MCU subsystem reference clock control 2
PERI_CLK_STP0	0x98	MCU peripherals clock on/off control 1
PERI_CLK_STP1	0x99	MCU peripherals clock on/off control 2
PERI_CLK_STP2	0x9A	MCU peripherals clock on/off control 3

### Power Control SFR

Please refer to Sec 8. power management for the more details.

Register	Address	Description
PCON	0x87	Power control register

Bit Field	Name	Descriptions	RW	Reset Value
7:2		Reserved bits		0
1	PD	Power-down mode bit 1: start power-down mode 0: clear by hardware when an enabled external interrupt or a reset occurs.	R/W	0
0		Reserved bit		0

### 8051 MCU Interrupt SFRs

Please refer to Sec 7.4. interrupt for the more details.

Register	Address	Description
IE	0xA8	Interrupt Enable
EIE1	0xE8	Extended Interrupt Enable 1
EIE2	0xE9	Extended Interrupt Enable 2
IP	0xB8	Interrupt Priority
EIP1	0xF8	Extended Interrupt Priority 1
EIP2	0xF9	Extended Interrupt Priority 2
EXIF2	0xD8	Extended Interrupt Flag 2
EXIF1	0x91	Extended Interrupt Flag 1

## 7.2. Clock

The MG2470 supports an advanced and flexible clock selection function to reduce the power consumption depending on the target applications. The clock system overview of MG2470 is shown in the [Figure 7].

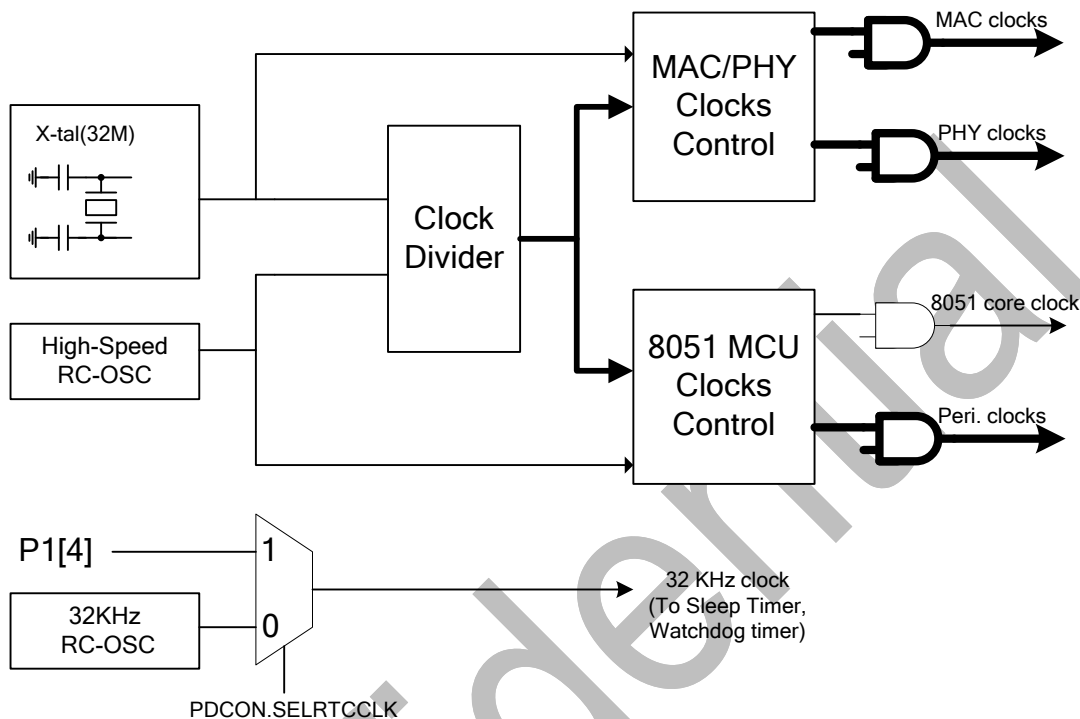


Figure 7. Clock System Overview

Two high speed oscillators are included in the MG2470. One is 32 MHz crystal oscillator and the other is high speed RC oscillator (HSRCOSC). The high speed crystal oscillator startup time may be too long for the power critical applications. For example, the wake-up time from the power down mode is longer than the RC oscillator. So, the MG2470 can run on the high speed RCOSC until the crystal oscillator is stable.

### 7.2.1. 8051 MCU Reference Clock Control

The 8 MHz clock source from 32MHz crystal and a high-speed RC oscillator can be used to drive the internal 8051 MCU clock in MG2470. The default clock frequency of MG2470 is 8 MHz. When selecting 8051 MCU clock, the SFR CLKCON1 should be set as follows;

#### MCU subsystem Reference Clock Control 1 (CLKCON1, 0x8E)

Bit Field	Name	Descriptions	RW	Reset Value
7	CLK8M_DIV[2]		R/W	000
6	CLK8M_DIV[1]			

5	CLK8M_DIV[0]	<b>Value</b>	<b>CLK8M divider ratio</b>		
		000	CLK8M is divided by 1(8MHz)		
		001	CLK8M/2(4MHz)		
		010	CLK8M/4(2MHz)		
		011	CLK8M/8(1MHz)		
		100	CLK8M/32(0.25 MHz)		
		101	CLK8M/512(15.625 KHz)		
		110	CLK8M/4096(1.953 KHz)		
111	CLK8M/16384(488 Hz)				
4	HSRCOSC_SEL	HS RCOSC selection 1: the clock selected is the HS RCOSC source 0: the 8MHz from 32MHz crystal is selected	R/W	0	
3:0		Reserved bits (These bits must be set to 4'b0000 for normal operation.)	R/W	4'b0000	

#### MCU subsystem Reference Clock Control 2(CLKCON2, 0x8F)

Bit Field	Name	Descriptions	RW	Reset Value
7	MCU_INIT_WAIT	This bit is the status flag for detecting the MCU internal clock state change.	R	0
6	HSRCOSC_ST S	When the MG2470 is gone into the power-down mode, this bit is set to 1. The HS RCOSC source is used as the wake-up clock when exiting from the power-down mode. In order to return to the normal mode, this bit should be cleared by SFR write operation to CLKCON2.	R/W	0
5:0	Reserved	This value read from this bits is 0	R	0

The 8051 MCU clock should be changed to normal clock sources after a power-down by SFR CLKCON2 register setting. Please take care of this register setting at wake-up time from a power-down mode.

#### 7.2.2. MCU Peripherals Clock Control

The operating clock of 8051 MCU peripherals can be enabled or disabled by some SFR registers write operation. For details, please refer to the SFRs description below.

##### Peripheral Clock Stop 0(PERI\_CLK\_STP0, 0x98)

Bit Field	Name	Descriptions	R/W	Reset Value
7	SPI_ON	This bit is for enabling or disabling the operating clock of SPI. 0 : clock is off 1 : clock is on	R/W	0
6	UART1_ON	This bit is for enabling or disabling the operating clock of UART1. 0 : clock is off	R/W	1

		1 : clock is on		
5	UART0_ON	This bit is for enabling or disabling the operating clock of UART0. 0 : clock is off 1 : clock is on	R/W	1
4	GPIO_ON	This bit is for enabling or disabling the operating clock of GPIO. 0 : clock is off 1 : clock is on	R/W	1
3	PWM_ON	This bit is for enabling or disabling the operating clock of PWM. 0 : clock is off 1 : clock is on	R/W	0
2		Reserved		
1	WDT_ON	This bit is for enabling or disabling the operating clock of WDT. 0 : clock is off 1 : clock is on	R/W	1
0	TIMER01_ON	This bit is for enabling or disabling the operating clock of timer 0/1. 0 : clock is off 1 : clock is on	R/W	1

#### Peripheral Clock Stop 1(PERI\_CLK\_STP1, 0x99)

Bit Field	Name	Descriptions	R/W	Reset Value
7	Reserved		R/W	0
6	IRTX_ON	This bit is for enabling or disabling the operating clock of IR TX modulator. 0 : clock is off 1 : clock is on	R/W	0
5	FLASHC_ON	This bit is for enabling or disabling the operating clock of flash controller. 0 : clock is off 1 : clock is on	R/W	0
4	VOICE_ON	This bit is for enabling or disabling the operating clock of voice block. 0 : clock is off 1 : clock is on	R/W	0
3	I2SRX_ON	This bit is for enabling or disabling the operating clock of I2S RX. 0 : clock is off 1 : clock is on	R/W	0
2	I2STX_ON	This bit is for enabling or disabling the operating clock of I2S TX. 0 : clock is off 1 : clock is on	R/W	0
1	QUAD_ON	This bit is for enabling or disabling the operating clock of quadrature signal decoder. 0 : clock is off 1 : clock is on	R/W	0
0	RNG_ON	This bit is for enabling or disabling the operating clock of random number	R/W	0

		generator. 0 : clock is off 1 : clock is on		
--	--	---	--	--

### Peripheral Clock Stop 2(PERI\_CLK\_STP2, 0x9A)

Bit Field	Name	Descriptions	R/W	Reset Value
7:3		Reserved bits	R	0
2	MPTOP_ON	This bit is for enabling or disabling the operating clock of MAC/PHY registers interface block. 0 : clock is off 1 : clock is on	R/W	1
1	LOGIC3V_ON	This bit is for enabling or disabling the operating clock of LOGIC3V registers interface block. 0 : clock is off 1 : clock is on	R/W	1
0	CLKRST_CTL_ON	This bit is for enabling or disabling the operating clock of clock & reset controller. 0 : clock is off 1 : clock is on	R/W	1

### 7.2.3. MAC/PHY Clocks Control

Please refer to the clock & reset in Section 8.1 of peripherals chapter for details.

## 7.3. Resets

The MG2470 has four types of reset sources.

- The external pin RESETB is inputted to low during more than 62.5 us
- Internal POR(Power-On-Reset) condition
- Internal BOD(Brown Out Detector) reset condition
- Watchdog timer reset condition

The initial conditions after a reset are as follows;

- I/O pins are configured as inputs with pull-up
- CPU program counter is loaded with 0x0000 and program execution starts at this address
- All peripheral registers are initialized to their reset values.
- Watchdog time is enabled

The resets of MAC/PHY blocks are controlled by the separate reset controller block in the MG2470. They can be reset by S/W control besides four sources for system reset. For more detailed information, please refer to the register description in the clock & reset controller(Sec 9.1).



### 7.4. Interrupts

The 8051 MCU of MG2470 employs a program interrupt method similar to the one of other MCU. When the interrupt event occurs, the 8051 CPU core jumps to the location which is called as an interrupt vector address and the interrupt service routine at the corresponding vector address is executed. When the interrupt subroutine completes, execution resumes at the point where the interrupt occurred. Interrupts can occur as a result of internal activity (e.g. timer0 overflow) or at the initiation of an external device (external interrupt pin). All the interrupts of MG2470 can be enabled or disabled dynamically by user.

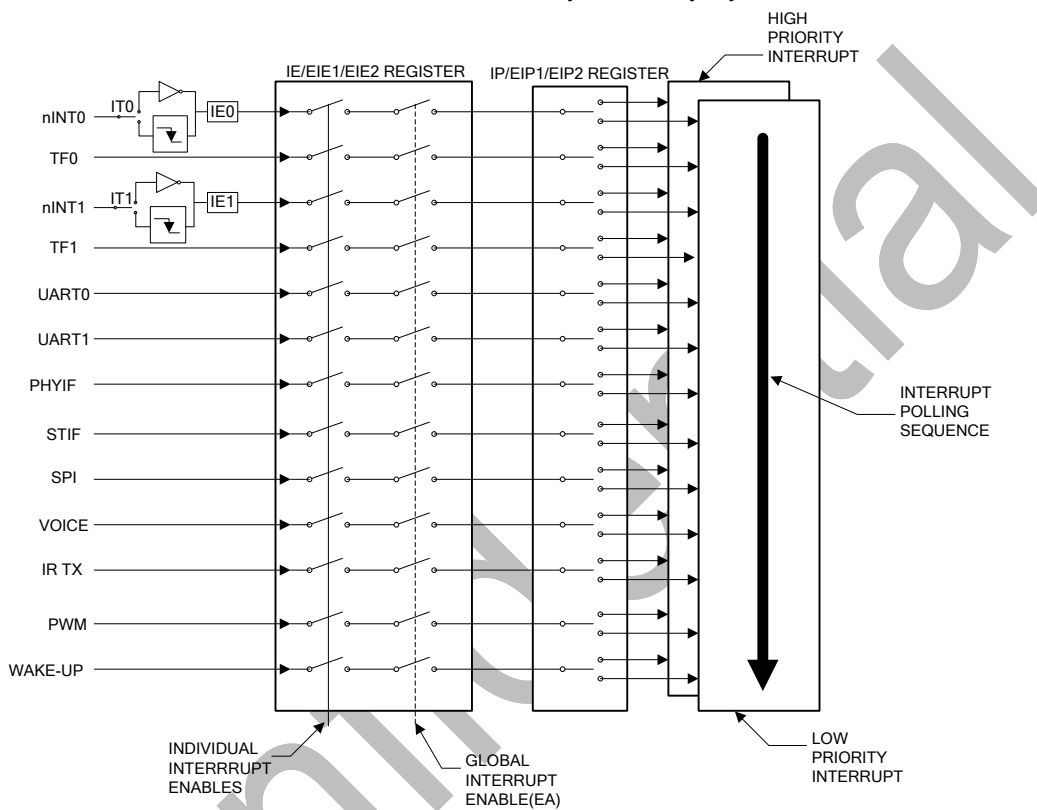


Figure 8. Interrupts Overview of MG2470

MG2470 has 13 interrupt sources. [Table 4] describes the detailed information for each of the interrupt sources. The 'Interrupt Address' indicates the address where the interrupt service routine is located. The 'Interrupt Flag' is the bit that notifies the MCU that the corresponding interrupt has occurred. 'Interrupt Enable' is the bit which decides whether each interrupt has been enabled. 'Interrupt Priority' is the bit which decides the priority of the interrupt. 'Interrupt Number' is the interrupt priority fixed by the hardware. That is, when two or more interrupts having the same 'Interrupt Priority' value, occur simultaneously, the lower 'Interrupt Number' is processed first.

Table 4. Interrupt Descriptions

Interrupt Number	Interrupt Type	Interrupt Address	Interrupt Flag	Interrupt Enable	Interrupt Priority
0	External Interrupt0	0x0003	TCON.IE0 (TCON[1])	IE.EX0 (IE[0])	IP[0]
1	Timer0 Interrupt	0x000B	TCON.TF0 (TCON[5])	IE.ET0 (IE[1])	IP[1]

2	External Interrupt1	0x0013	TCON.IE1 (TCON[3])	IE.EX1 (IE[2])	IP[2]
3	Timer1 Interrupt	0x001B	TCON.TF1 (TCON[7])	IE.ET1 (IE[3])	IP[3]
4	UART0 Interrupt	0x0023	Refer to Note1	IE.ES0 (IE[4])	IP[4]
5	IR TX Interrupt	0x002B	Refer to Note5	EIE2[0]	EIP2[0]
6	Reserved	0x0033			
7	UART1 Interrupt	0x003B	Refer to Note1	IE.ES1 (IE[6])	IP[6]
8	PHY Interrupt	0x0043	EXIF1.PHYIF (EXIF1[4])	EIE1.PHYIE (EIE1[0])	EIP1[0]
9	Reserved	0x004B			
10	Reserved	0x0053			
11	Reserved	0x005B			
12	SleepTimer time-out Interrupt	0x0063	EXIF2.STIF (EXIF2[1])	EIE1.STIE (EIE1[4])	EIP1[4]
13	SPI Interrupt	0x006B	Refer to Note2	EIE1.SPIIE (EIE1[5])	EIP1[5]
14	DMA Interrupt	0x0073	Refer to Note3	EIE1.DMAIE (EIE1[6])	EIP1[6]
15	Wake-up Interrupt	0x007B	EXIF2.WUIF (EXIF2[0])	EIE1.WUIE (EIE1[7])	EIP1[7]
16	Reserved	0x0083			
17	PWM Interrupt	0x008B	Refer to Note 4	EIE2[3]	EIP2[3]

**Note 1:** In case of a UART Interrupt, bit[0] of the IIR register(0x2502,0x2512) in the UART block is used as a flag. Also, the Tx, Rx, Timeout, Line Status and Modem Status interrupts can be distinguished by bit[3:1] value. For more detailed information, refer to the UART0/1 description in Section 8.6.

**Note 2:** In case of an SPI interrupt, there is another interrupt enable bit in the SPI register besides EIE.SPIIE. In order to enable SPI interrupt, both SPIE in SPCR (0x2540) register and EIE.SPIIE should be set to '1'. And, SPIF in SPSR (0x2541) register acts as an interrupt flag.

**Note 3:** In case of a DMA interrupt, there are interrupt enable register and interrupt flag register in voice block. The interrupt enable register are VTFINTENA (0x2770), VRFINTENA (0x2771) and VDMINTENA (0x2772). There are 24 interrupt sources. When both an interrupt enable signal and an interrupt flag signal are set to '1,' DMA interrupt is enabled.

**Note 4:** In case of a PWM interrupt, please refer to the PWM section (8.4)

**Note 5:** In case of an IR TX interrupt, please refer to the IR Modulator section (8.10)

### 7.4.1. Interrupt Sources

The MG2470 has the 13 hardware interrupt sources. They include two external interrupts (nINT0 & nINT1), two timers interrupt timers 0/1, two UART interrupts and ten additional interrupt. Each interrupt has an interrupt request flag and for some interrupts, hardware clears the request flag when it grants an interrupt. The followings are interrupt sources in the MG2470.

- External interrupts(IE0 and IE1 in TCON register)
- PHY interrupt
- Sleep timer time-out interrupt
- MCU peripherals interrupt
  - ✓ Timer 0&1 (TF0 and TF1 in TCON register)
  - ✓ UART0 & UART1
  - ✓ SPI
  - ✓ DMA
  - ✓ 5-channel PWM
  - ✓ IR modulator
- Wake-up interrupt from the power-down mode

#### EXTENDED INTERRUPT FLAG REGISTER 1 (EXIF1, 0x91)

This register stores the interrupt state corresponding to each bit. When the interrupt corresponding to a bit is triggered, the flag is set to '1'.

Bit Field	Name	Descriptions	R/W	Reset Value
7:5		Reserved bits		
4	PHYIF	PHY interrupt flag 0: No interrupt 1: Interrupt pending *Note: To clear the interrupt flag, The 0 must be written into this bit.	R/W	0
3:0		Reserved bits		

#### EXTENDED INTERRUPT FLAG REGISTER 2 (EXIF2, 0xD8)

Bit Field	Name	Descriptions	R/W	Reset Value
7:2		Reserved	R	0
1	STIF	Sleep timer time-out interrupt flag under normal mode. 0: No interrupt 1: Interrupt pending *Note: To clear the interrupt flag, 1 must be written into this bit.	R/W	0

0	WUIF	Power-down wake-up interrupt flag 0: No interrupt 1: Interrupt pending *Note: To clear the interrupt flag, 1 must be written into this bit.	R/W	0
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### 7.4.2. Interrupt Enable

The EA bit in the IE register is the global interrupt enable signal for all interrupts. In addition, each interrupt is masked by each interrupt enable bit. Therefore, in order to use an interrupt, both EA and the specific interrupt enable bit should be set to '1'. When the bit for each interrupt is '0', that interrupt is disabled. When the bit for each interrupt is '1', that interrupt is enabled.

#### Interrupt Enable Register (IE, 0xA8)

Bit Field	Name	Descriptions	R/W	Reset Value
7	EA	Global interrupt enable 0: No interrupt will be acknowledged. 1: Each interrupt source is individually enabled or disabled by setting its corresponding enable bit.	R/W	0
6	ES1	UART1 interrupt enable 0: interrupt disabled 1: interrupt enabled (EA bit should be set to '1')	R/W	0
5		Reserved		0
4	ES0	UART0 interrupt enable 0: interrupt disabled 1: interrupt enabled (EA bit should be set to '1')	R/W	0
3	ET1	Timer1 interrupt enable 0: interrupt disabled 1: interrupt enabled (EA bit should be set to '1')	R/W	0
2	EX1	External interrupt1 enable 0: interrupt disabled 1: interrupt enabled (EA bit should be set to '1')	R/W	0
1	ET0	Timer0 interrupt enable 0: interrupt disabled 1: interrupt enabled (EA bit should be set to '1')	R/W	0
0	EX0	External interrupt0 enable	R/W	0

		0: interrupt disabled 1: interrupt enabled (EA bit should be set to '1')		
--	--	--	--	--

**Extended Interrupt Enable Register 1(EIE1, 0xE8)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	WUIE	Wake-up from the power-down mode interrupt enable 0: interrupt disabled 1: interrupt enabled	R/W	0
6	DMAIE	DMA interrupt enable 0: interrupt disabled 1: interrupt enabled	R/W	0
5	SPIIE	SPI interrupt enable 0: interrupt disabled 1: interrupt enabled	R/W	0
4	STIE	Sleep Timer Time-out interrupt enable 0: interrupt disabled 1: interrupt enabled	R/W	0
3:1		Reserved bits		
0	PHYIE	PHY interrupt enable 0: interrupt disabled 1: interrupt enabled	R/W	0

**Extended Interrupt Enable Register 2(EIE2, 0xE9)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:4		Reserved bits	R	0
3	EIE2[3]	PWM interrupt enable 0: interrupt disabled 1: interrupt enabled	R/W	0
2:1		Reserved bits		
0	EIE2[0]	IR TX interrupt enable 0: interrupt disabled 1: interrupt enabled	R/W	0

**7.4.3. Interrupt Priority**

Each interrupt source can also be individually programmed to one of two priority levels by setting or clearing a bit in SFRs IP/EIP1/EIP2. A low-priority interrupt can itself be interrupted by a high-priority interrupt, but not by another low-priority interrupt. A high-priority interrupt can't be interrupted by any other interrupt source.

**INTERRUPT PRIORITY REGISTER (IP, 0xB8)**

If a bit corresponding to each interrupt is '0', the corresponding interrupt has lower priority and if a bit is '1', the corresponding interrupt has higher priority.

Bit Field	Name	Descriptions	R/W	Reset Value
7		Reserved		0
6	PS1	UART1 interrupt priority bit 0: assign low priority 1: assign high priority	R/W	0
5		Reserved		0
4	PS0	UART 0 interrupt priority bit 0: assign low priority 1: assign high priority	R/W	0
3	PT1	Timer1 interrupt priority bit 0: assign low priority 1: assign high priority	R/W	0
2	PX1	External interrupt1 interrupt priority bit 0: assign low priority 1: assign high priority	R/W	0
1	PT0	Timer0 interrupt priority bit 0: assign low priority 1: assign high priority	R/W	0
0	PX0	External interrupt0 interrupt priority bit 0: assign low priority 1: assign high priority	R/W	0

**EXTENDED INTERRUPT PRIORITY REGISTER 1 (EIP1, 0xF8)**

Bit Field	Name	Descriptions	R/W	Reset Value
7		Reserved		0
6	DMAIP	DMA interrupt priority bit 1: DMA interrupt has higher priority. 0: DMA interrupt has lower priority.	R/W	0
5	SPIIP	SPI interrupt priority bit 1: PI interrupt has higher priority. 0: PI interrupt has lower priority.	R/W	0
4	RTCIP	Sleep Timer time-out interrupt priority bit 1: Sleep Timer interrupt has higher priority. 0: Sleep Timer interrupt has lower priority.	R/W	0
3:1		Reserved bits		
0	PHYIP	PHY interrupt priority bit	R/W	0

		1: PHY interrupt has higher priority. 0: PHY interrupt has lower priority.		
--	--	---	--	--

**EXTENDED INTERRUPT PRIORITY REGISTER 2 (EIP2, 0xF9)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:4		Reserved bits		
3	PWMIP	PWM interrupt priority bit 1: PWM interrupt has higher priority. 0: PWM interrupt has lower priority.	R/W	0
2:1		Reserved bits		
0	IRTXIP	IR TX interrupt priority 1: IR TX interrupt has higher priority. 0: IR TX interrupt has lower priority.	R/W	0

## 8. PERIPHERALS

### 8.1. Clock and Reset Controller

This block supports the clock on/off and SW resets for the individual blocks in the MAC/PHY or RF/Analog. Also, it selects the ADC sampling clock of ADC decimator block and controls the clock output function for supplying the clock to external devices.

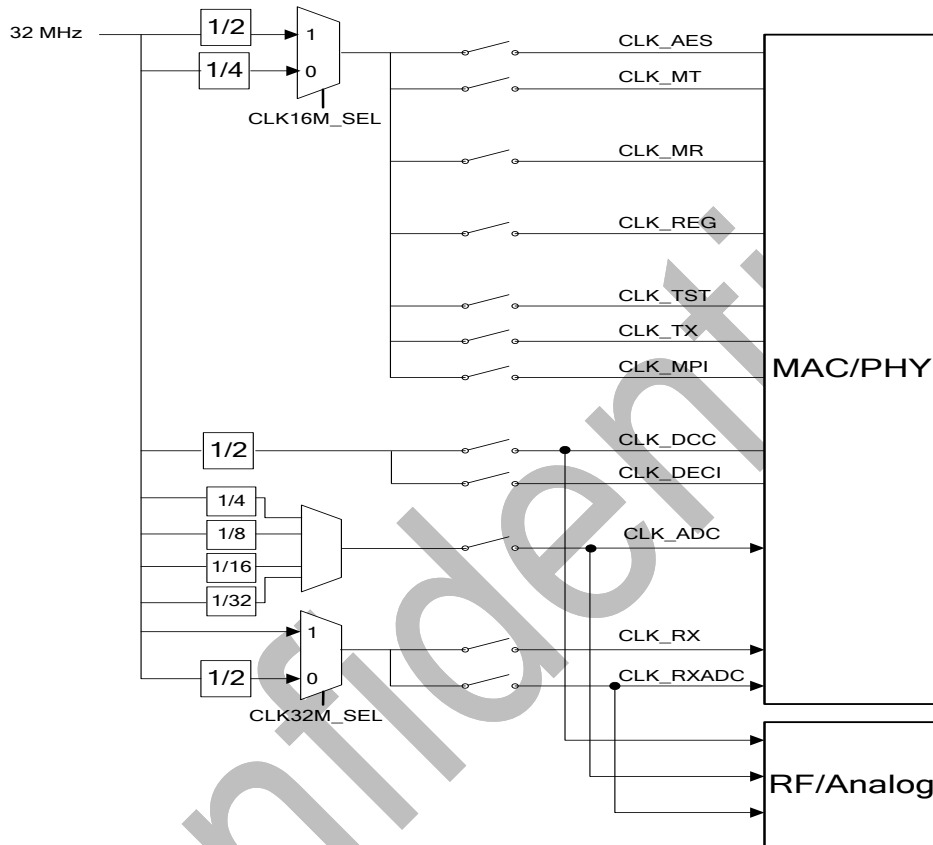


Figure 9. Clocks Structure of the MAC/PHY block

#### PHY\_CLK\_EN0 (PHY Clock Enable Register 0, 0x2780)

This register is used to enable or disable clocks of the MAC/PHY block.

Bit Field	Name	Descriptions	R/W	Reset Value
7	CLK_MPI_EN	CLK_MPI clock on/off control bit 0: clock disabled 1: clock enabled	R/W	0
6	CLK_RX_EN	CLK_RX clock on/off control bit 0: clock disabled 1: clock enabled	R/W	0
5	CLK_REG_EN	CLK_REG clock on/off control bit 0: clock disabled 1: clock enabled	R/W	0
4	CLK_TX_EN	CLK_TX clock on/off control bit	R/W	0



		0: clock disabled 1: clock enabled		
3	CLK_TST_EN	CLK_TST clock on/off control bit 0: clock disabled 1: clock enabled	R/W	0
2	CLK_MR_EN	CLK_MR clock on/off control bit 0: clock disabled 1: clock enabled	R/W	0
1	CLK_MT_EN	CLK_MT clock on/off control bit 0: clock disabled 1: clock enabled	R/W	0
0	CLK_AES_EN	CLK_AES clock on/off control bit 0: clock disabled 1: clock enabled	R/W	0

### PHY\_CLK\_EN1 (PHY Clock Enable Register 1, 0x2781)

This register is used to enable or disable clocks of the MAC/PHY or RF/Analog block.

Bit Field	Name	Descriptions	R/W	Reset Value
7:6		Reserved	R	0
5	DCCLK_EN	DCCLK (16MHz) clock on/off control bit 0: clock disabled 1: clock enabled	R/W	0
4	Reserved			0
3	CLK_ADC_EN	CLK_ADC clock on/off control bit 0: clock disabled 1: clock enabled	R/W	0
2	CLK_DECI_EN	CLK_DECI clock on/off control bit 0: clock disabled 1: clock enabled	R/W	0
1		Reserved		
0	CLK_RXADC_EN	CLK_RXADC clock on/off control bit 0: clock disabled 1: clock enabled	R/W	0

### PHY\_CLK\_FR\_EN0 (PHY Clock Force Enable Register 0, 0x2782)

This register is always used to enable the clock regardless of clock enable registers setting.

Bit Field	Name	Descriptions	R/W	Reset Value
7	CLK_MPI_FR_EN	Force the CLK_MPI clock to be enabled regardless of CLK_MPI_EN bit setting 0: clock is not forced to be enabled 1: clock is forced to be enabled	R/W	0

6	CLK_RX_FR_EN	Force the CLK_RX clock to be enabled regardless of CLK_RX_EN bit setting 0: clock is not forced to be enabled 1: clock is forced to be enabled	R/W	0
5	CLK_REG_FR_EN	Force the CLK_REG clock to be enabled regardless of CLK_REG_EN bit setting 0: clock is not forced to be enabled 1: clock is forced to be enabled	R/W	0
4	CLK_TX_FR_EN	Force the CLK_TX clock to be enabled regardless of CLK_TX_EN bit setting 0: clock is not forced to be enabled 1: clock is forced to be enabled	R/W	0
3	CLK_TST_FR_EN	Force the CLK_TST clock to be enabled regardless of CLK_TST_EN bit setting 0: clock is not forced to be enabled 1: clock is forced to be enabled	R/W	0
2	CLK_MR_FR_EN	Force the CLK_MR clock to be enabled regardless of CLK_MR_EN bit setting 0: clock is not forced to be enabled 1: clock is forced to be enabled	R/W	0
1	CLK_MT_FR_EN	Force the CLK_MT clock to be enabled regardless of CLK_MT_EN bit setting 0: clock is not forced to be enabled 1: clock is forced to be enabled	R/W	0
0	CLK_AES_FR_EN	Force the CLK_AES clock to be enabled regardless of CLK_AES_EN bit setting 0: clock is not forced to be enabled 1: clock is forced to be enabled	R/W	0

### PHY\_CLK\_FR\_EN1 (PHY Clock Force Enable Register 1, 0x2783)

This register is always used to enable the clock regardless of clock enable registers setting.

Bit Field	Name	Descriptions	R/W	Reset Value
7:6		Reserved	R	0
5	DCCLK_FR_EN	Force the DCCLK clock to be enabled regardless of DCCLK_EN bit setting 0: clock is not forced to be enabled 1: clock is forced to be enabled	R/W	0
4	OSCLK_FR_EN	Force the OSCLK clock to be enabled regardless of OSCLK_EN bit setting 0: clock is not forced to be enabled 1: clock is forced to be enabled	R/W	0
3	CLK_ADC_FR_EN	Force the CLK_ADC clock to be enabled regardless of CLK_ADC_EN bit setting 0: clock is not forced to be enabled	R/W	0

		1: clock is forced to be enabled		
2	CLK_DECI_FR_EN	Force the CLK_DECI clock to be enabled regardless of CLK_DECI_EN bit setting 0: clock is not forced to be enabled 1: clock is forced to be enabled	R/W	0
1		Reserved		
0	CLK_RXADC_FR_EN	Force the CLK_RXADC clock to be enabled regardless of CLK_RXADC_EN bit setting 0: clock is not forced to be enabled 1: clock is forced to be enabled	R/W	0

### PHY\_SW\_RSTB (PHY S/W Reset Register, 0x2784)

This register is used to control the S/W resets of the MAC/PHY block. The active reset level is low.

Bit Field	Name	Descriptions	R/W	Reset Value
7		Reserved	R	1
6	RESETB_DECI	RESETB_DECI reset signal control bit 0: RESETB_DECI active 1: RESETB_DECI inactive	R/W	1
5	RESETB_MAC	RESETB_MAC reset signal control bit 0: RESETB_MAC active 1: RESETB_MAC inactive	R/W	1
4	RESETB_MPI	RESETB_MPI reset signal control bit 0: RESETB_MPI active 1: RESETB_MPI inactive	R/W	1
3	RESETB_REG	RESETB_REG reset signal control bit 0: RESETB_REG active 1: RESETB_REG inactive	R/W	1
2	RESETB_RF	RESETB_RF reset signal control bit 0: RESETB_RF active 1: RESETB_RF inactive	R/W	1
1	RESETB_TX	RESETB_TX reset signal control bit 0: RESETB_TX active 1: RESETB_TX inactive	R/W	1
0	RESETB_RX	RESETB_RX reset signal control bit 0: RESETB_RX active 1: RESETB_RX inactive	R/W	1

### MPTOP\_CLK\_SEL (MAC/PHY Reference Clock Selection Register, 0x2785)

This register selects the reference clock of the MAC/PHY blocks. The default operating frequency of MAC/PHY block is 8 MHz/16MHz combination. The selectable combination is either 8/16 MHz or 16/32 MHz.

Bit	Name	Descriptions	R/W	Reset
-----	------	--------------	-----	-------

Field				Value
7:2		Reserved	R	0
1	CLK16M_SEL	Select the 8 MHz or 16 MHz 0: 8 MHz clock selected 1: 16 MHz clock selected	R/W	0
0	CLK32M_SEL	Select the 16 MHz or 32 MHz 0: 16 MHz clock selected 1: 32 MHz clock selected	R/W	0

### ADC\_CLK\_SEL (ADC Sampling Clock Selection Register, 0x2786)

This register selects the ADC sampling clock to ADC decimator block.

Bit Field	Name	Descriptions	R/W	Reset Value										
7:2		Reserved	R	0										
1	ADC_CLK_SEL[1]	<table border="1"> <thead> <tr> <th>Bit values</th> <th>ADC sampling clock</th> </tr> </thead> <tbody> <tr> <td>00</td> <td>1 MHz</td> </tr> <tr> <td>01</td> <td>2 MHz</td> </tr> <tr> <td>10</td> <td>4 MHz</td> </tr> <tr> <td>11</td> <td>Not valid</td> </tr> </tbody> </table>	Bit values	ADC sampling clock	00	1 MHz	01	2 MHz	10	4 MHz	11	Not valid	R/W	10
Bit values	ADC sampling clock													
00	1 MHz													
01	2 MHz													
10	4 MHz													
11	Not valid													
0	ADC_CLK_SEL[0]													

### EXT\_CLK\_CTL (External Clock Output Control Register, 0x2787)

The MG2470 supports the external clock output function to interface with the external devices. The selectable clock is as following table and is output to P1[3] when the clock output function is enabled. The default value is the clock output disabled.

Bit Field	Name	Descriptions	R/W	Reset Value																
7	EXT_CLK_EN	Enable the external clock output function 0: output is disabled 1: output is enabled	R/W	0																
6:3		Reserved	R	0																
2	EXT_CLK_SEL[2]	<table border="1"> <thead> <tr> <th>Bits values</th> <th>External clock frequency</th> </tr> </thead> <tbody> <tr> <td>000</td> <td>500 KHz</td> </tr> <tr> <td>001</td> <td>1 MHz</td> </tr> <tr> <td>010</td> <td>2 MHz</td> </tr> <tr> <td>011</td> <td>4 MHz</td> </tr> <tr> <td>100</td> <td>8 MHz</td> </tr> <tr> <td>101</td> <td>16 MHz</td> </tr> <tr> <td>110</td> <td>32 MHz</td> </tr> </tbody> </table>	Bits values	External clock frequency	000	500 KHz	001	1 MHz	010	2 MHz	011	4 MHz	100	8 MHz	101	16 MHz	110	32 MHz	R/W	0
Bits values	External clock frequency																			
000	500 KHz																			
001	1 MHz																			
010	2 MHz																			
011	4 MHz																			
100	8 MHz																			
101	16 MHz																			
110	32 MHz																			
1	EXT_CLK_SEL[1]		R/W	0																
0	EXT_CLK_SEL[0]		R/W	0																

		111	Clock is the off-state		
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## 8.2. Input/Output Ports(GPIO)

The MG2470-F48 has 22 general purpose pins which have the following key features.

- General I/O pins with selectable direction for each bit
- Programmable pull-up/down control for each bit
- Driving strength control for each bit
- External input disabling function for each bit
- External interrupt capability for P3[3:2] pins

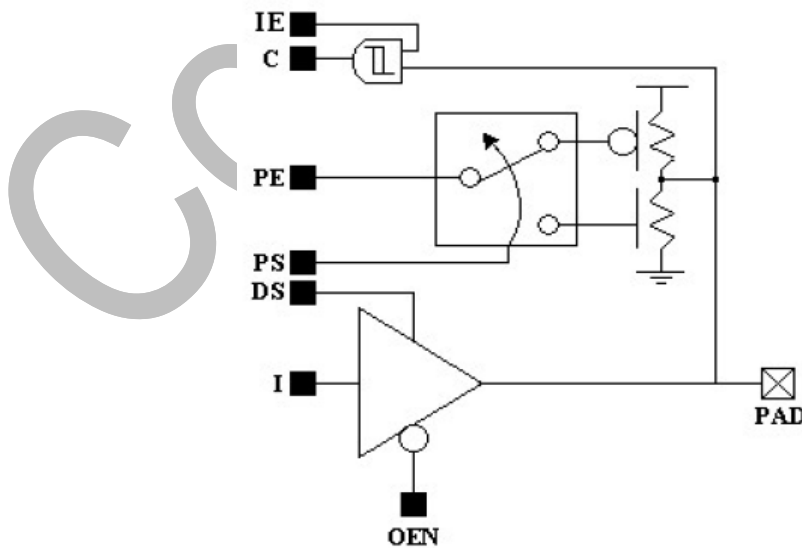
(These lines can be used to wake up the MG2470 from power down modes.)

The GPIO functions are listed in [Table 5]. [Figure 10] shows the block diagram of the GPIO. The GPIO pins after a reset are configured as inputs with pull-up.

**Table 5. PORT-0/1/3 Operation Truth Table**

INPUTs				OUTPUT
OEN	I	PE	PS	PAD
0	0	x	x	0
0	1	x	x	1
1	x	0	x	Hi-Z
1	x	1	0	Pull-down
1	x	1	1	Pull-up

DS	Current Spec.
0	Low-drive
1	High-drive



**Figure 10. PORT-0/1/3 PAD Block Diagram**

### 8.2.1. Port Data Registers(SFR area)

#### PORT-3 DATA REGISTER (P3, 0xB0)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	P3[7:0]	<p>This port register is used as a general purpose I/O ports.</p> <p>When reading the each bit of PORT-3, the current status value of the corresponding bit is returned.</p> <p>When writing the each bit of PORT-3, the corresponding PORT-3 bit is changed to the new value. By default, the direction of P3[7:0] is the input mode and the pull-up enable bit is the active-state.</p> <p>For details of pull-up/pull-down controls of P3[7:0], Please see to the Power Management section(7.5).</p>	R/W	Unknown

#### PORT-1 DATA REGISTER (P1, 0x90)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	P1[7:0]	<p>This port register is used as a general purpose I/O ports.</p> <p>When reading the each bit of PORT-1, the current status value of the corresponding bit is returned.</p> <p>When writing the each bit of PORT-1, the corresponding PORT-1 bit is changed to the new value. By default, the direction of P1[7:0] is the input mode and the pull-up enable bit is the active-state.</p> <p>For details of pull-up/pull-down controls of P1[7:0], Please see to the Power Management section(7.5).</p>	R/W	Unknown

#### PORT-0 DATA REGISTER (P0, 0x80)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	P0[7:0]	<p>This port register is used as a general purpose I/O ports.</p> <p>When reading the each bit of PORT-0, the current status value of the corresponding bit is returned.</p> <p>When writing the each bit of PORT-0, the corresponding PORT-0 bit is changed to the new value. By default, the direction of P0[7:0] is the input mode and the pull-up enable bit is the active-state.</p> <p>For details of pull-up/pull-down controls of P0[7:0], Please see to the Power Management section(7.5).</p>	R/W	Unknown

### 8.2.2. Port Direction Registers(SFR area)

#### PORT-0 OUTPUT ENABLE REGISTER (P0OEN, 0xB1)

This register is SFR for setting the PORT-0 directions.

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	P0OEN[7:0]	When writing a '1' to the port direction SFR bit, sets the corresponding bit to be an input. Writing a '0' causes the port bit to be an output.	R/W	0xFF

#### PORT-1 OUTPUT ENABLE REGISTER (P1OEN, 0xB2)

This register is SFR for setting the PORT-1 directions.

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	P1OEN[7:0]	When writing a '1' to the port direction SFR bit, sets the corresponding bit to be an input. Writing a '0' causes the port bit to be an output.	R/W	0xFF

#### PORT-3 OUTPUT DATA REGISTER (P3OEN, 0xB4)

This register is SFR for setting the PORT-3 directions.

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	P3OEN[7:0]	When writing a '1' to the port direction SFR bit, sets the corresponding bit to be an input. Writing a '0' causes the port bit to be an output.	R/W	0xFF

### 8.2.3. Port Input Enable Registers (SFR area)

#### PORT-0 INPUT ENABLE REGISTER (P0\_IE, 0xB9)

This register is SFR for enabling or disabling the inputs from the external PORT-0 PADs. Please refer to Figure 10 and Table 5 above for PAD IN/OUT pins and operation modes.

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	P0_IE[7:0]	When writing a '1' to the PORT-0 PAD input enable SFR bit, enabled the input from the corresponding PORT-0 PAD. Writing a '0' causes the input from PAD to be disabled.	R/W	0xFF

#### PORT-1 INPUT ENABLE REGISTER (P1\_IE, 0xBA)

This register is SFR for enabling or disabling the inputs from the external PORT-1 PADs.

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	P1_IE[7:0]	When writing a '1' to the PORT-1 PAD input enable SFR bit, enabled the input from the corresponding PORT-1 PAD. Writing a '0' causes the input from PAD to be disabled.	R/W	0xFF

#### PORT-3 INPUT ENABLE REGISTER (P3\_IE, 0xBC)

This register is SFR for enabling or disabling the inputs from the external PORT-3 PADs.

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	P3_IE[7:0]	When writing a '1' to the PORT-3 PAD input enable SFR bit, enabled the input from the corresponding PORT-3 PAD.	R/W	0xFF

		Writing a '0' causes the input from PAD to be disabled.		
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### 8.2.4. Port Drive Strength Selection Registers (SFR area)

#### PORT-0 DRIVE STRENGTH SELECTION REGISTER (P0\_DS, 0xC1)

This register is SFR for selecting the drive strength capability of PORT-0.

Bit Field	Name	Descriptions	R/W	Reset Value
7	P0_DS[7]	Select the drive strength of P0[7]-pin (0 : 4 mA , 1: 8 mA)	R/W	0
6	P0_DS[6]	Select the drive strength of P0[6]-pin (0 : 4 mA , 1: 8 mA)	R/W	0
5	P0_DS[5]	Select the drive strength of P0[5]-pin (0 : 4 mA , 1: 8 mA)	R/W	0
4	P0_DS[4]	Select the drive strength of P0[4]-pin (0 : 12 mA , 1: 16 mA)	R/W	0
3	P0_DS[3]	Select the drive strength of P0[3]-pin (0 : 12 mA , 1: 16 mA)	R/W	0
2	P0_DS[2]	Select the drive strength of P0[2]-pin (0 : 12 mA , 1: 16 mA)	R/W	0
1	P0_DS[1]	Select the drive strength of P0[1]-pin (0 : 12 mA , 1: 16 mA)	R/W	0
0	P0_DS[0]	Select the drive strength of P0[0]-pin (0 : 12 mA , 1: 16 mA)	R/W	0

#### PORT-1 DRIVE STRENGTH SELECTION REGISTER (P1\_DS, 0xC2)

This register is SFR for selecting the drive strength capability of PORT-1.

Bit Field	Name	Descriptions	R/W	Reset Value
7	P1_DS[7]	Select the drive strength of P1[7]-pin (0 : 4 mA , 1: 8 mA)	R/W	0
6	P1_DS[6]	Select the drive strength of P1[6]-pin (0 : 4 mA , 1: 8 mA)	R/W	0
5	P1_DS[5]	Select the drive strength of P1[5]-pin (0 : 4 mA , 1: 8 mA)	R/W	0
4	P1_DS[4]	Select the drive strength of P1[4]-pin (0 : 4 mA , 1: 8 mA)	R/W	0
3	P1_DS[3]	Select the drive strength of P1[3]-pin (0 : 4 mA , 1: 8 mA)	R/W	0
2	P1_DS[2]	Select the drive strength of P0[2]-pin (0 : 4 mA , 1: 8 mA)	R/W	0
1	P1_DS[1]	Select the drive strength of P0[1]-pin (0 : 4 mA , 1: 8 mA)	R/W	0
0	P1_DS[0]	Select the drive strength of P0[0]-pin (0 : 4 mA , 1: 8 mA)	R/W	0

#### PORT-3 DRIVE STRENGTH SELECTION REGISTER (P3\_DS, 0xC4)

This register is SFR for selecting the drive strength capability of PORT-3.

Bit Field	Name	Descriptions	R/W	Reset Value
7	P3_DS[7]	Select the drive strength of P3[7]-pin (0 : 4 mA , 1: 8 mA)	R/W	0
6	P3_DS[6]	Select the drive strength of P3[6]-pin (0 : 4 mA , 1: 8 mA)	R/W	0
5	P3_DS[5]	Select the drive strength of P3[5]-pin (0 : 4 mA , 1: 8 mA)	R/W	0
4	P3_DS[4]	Select the drive strength of P3[4]-pin	R/W	0



		(0 : 4 mA , 1: 8 mA)		
3	P3_DS[3]	Select the drive strength of P3[3]-pin (0 : 4 mA , 1: 8 mA)	R/W	0
2	P3_DS[2]	Select the drive strength of P3[2]-pin (0 : 4 mA , 1: 8 mA)	R/W	0
1	P3_DS[1]	Select the drive strength of P3[1]-pin (0 : 4 mA , 1: 8 mA)	R/W	0
0	P3_DS[0]	Select the drive strength of P3[0]-pin (0 : 4 mA , 1: 8 mA)	R/W	0

### 8.2.5. Port Pull-up/down Control Registers

These registers are mapped to the DATA memory area and can be accessed by MOVX instruction of 8051 core. These registers value are retained in the power down mode. Please refer to the GPIOPS0/GPIOPE0, GPIOPS1/GPIOPE1, GPIOPS3/GPIOPE3 registers in the section 8.19 for details on the register setting.

## 8.3. TIMER 0/1

The Embedded MCU has two 16-bit timers which are compatible with Intel 8051 MCU (Timer0, Timer1). These timers have 2 modes; one is operated as a timer and the other is operated as a counter. When it is operated as a timer, there are 4 operating modes.

Each timer is 16-bit timer and consists of two 8-bit register. Therefore, the counter can be either 8-bit or 16-bit set by the operating mode.

In counter mode, the input signal T0 (P3 [4]) and T1 (P3 [5]) are sampled once every 12 cycles of the system clock. If the sampled value is changed from '1' to '0', the internal counter is incremented. In this time, the duty cycle of T0 and T1 doesn't affect the increment. Timer0 and Timer1 are accessed by using 6 SFR's.

The following table describes timer registers and modes.

### TCON (TIMER/COUNTER CONTROL REGISTER,0x88)

This register is used to control a timer function and monitor a timer status.

Bit Field	Name	Descriptions	R/W	Reset Value
7	TF1	Timer1 Overflow Flag. When this field is '1', a Timer1 interrupt occurs. After the Timer1 interrupt service routine is executed, this field value is cleared by hardware.	R/W	0
6	TR1	Timer1 Run Control. When this bit is set to '1', Timer1 is enabled.	R/W	0
5	TF0	Timer0 Interrupt Flag. 1: Interrupt is pending After Timer0 interrupt service routine is executed, this field is cleared by hardware.	R/W	0
4	TR0	Timer0 Run When this bit is set to '1', Timer0 is enabled.	R/W	0
3	IE1	External Interrupt1 Edge Flag. When this field is '1', External interrupt1 is pending. After the interrupt service routine is executed, this field is cleared by hardware.	R/W	0
2	IT1	External Interrupt1 Type Control. This field specifies the type of External interrupt1.	R/W	0

		1=Edge type. When the falling edge of INT1 is detected, the interrupt occurs. 0=Level type. When INT1 is low level, the interrupt occurs.		
1	IE0	External Interrupt0 Edge Flag. When this field is '1', External interrupt0 is pending. After the interrupt service routine is executed, this field is cleared by hardware.	R/W	0
0	IT0	External Interrupt0 Type Control. This field specifies the type of External interrupt0. 1=Edge type. When the falling edge of INT0 is detected, the interrupt occurs. 0=Level type. When INT0 is low level, the interrupt occurs.	R/W	0

**TMOD (TIMER/COUNTER MODE CONTROL REGISTER, 0x89)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	GATE 1	Timer Gate Control When TR1 is set to '1' and GATE1 is '1', Timer1 is enabled only while INT1 pin is high. When GATE1 is set to '0', Timer1 is enabled whenever TR1 control is set to '1'.	R/W	0
6	CT1	Timer1 Counter Mode Select When this field is set to '1', Timer1 is enabled as counter mode.	R/W	0
5:4	M1	Timer1 mode select. 0: Mode0, 12-bit Timer 1: Mode1, 16-bit Timer 2: Mode2, 8-bit Timer with auto-load 3: Mode3, two 8-bit Timer	R/W	0
3	GATE 0	Timer0 Gate Control. When TR0 is set to '1' and GATE0 is '1', Timer0 is enabled while INT0 pin is in high. When GATE1 is set to '0' and TR1 is set to '1', Timer0 is enabled.	R/W	0
2	CT0	When this field is set to '1', Timer0 is enabled as counter mode.	R/W	0
1:0	M0	Timer0 mode select 0: Mode0, 12-bit Timer 1: Mode1, 16-bit Timer 2: Mode2, 8-bit Timer with auto-load 3: Mode3, two 8-bit Timer	R/W	0

**TL0/TL1/TH0/TH1 (TIMER REGISTERS, 0x8A, 0x8B, 0x8C, 0x8D)**

A pair of register, which are (TH0, TL0) and (TH1, TL1), can be used as 16-bit timer register for Timer0 and Timer1 and it can be used as 8-bit register respectively.

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	TH1	Timer1 High Byte Data	R/W	0x00

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	TH0	Timer0 High Byte Data	R/W	0x00

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	TL1	Timer1 Low Byte Data	R/W	0x00

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	TL0	Timer0 Low Byte Data	R/W	0x00

In mode0, 12-bit register of timer0 consists of 7-bit of TH0 and the lower 5-bit of TL0. The higher 1-bit of TH0 and higher 3-bit of TL0 are disregarded. When this 12-bit register is overflowed, set TF0 to '1'. The operation of timer1 is same as that of timer0.

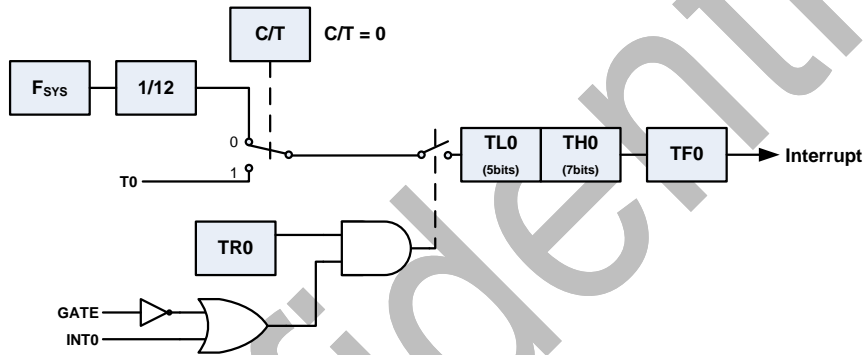


Figure 11. Timer0 Mode0

In Mode1, the operation is same as it of Mode0 except all timer registers are enabled as a 16-bit counter.

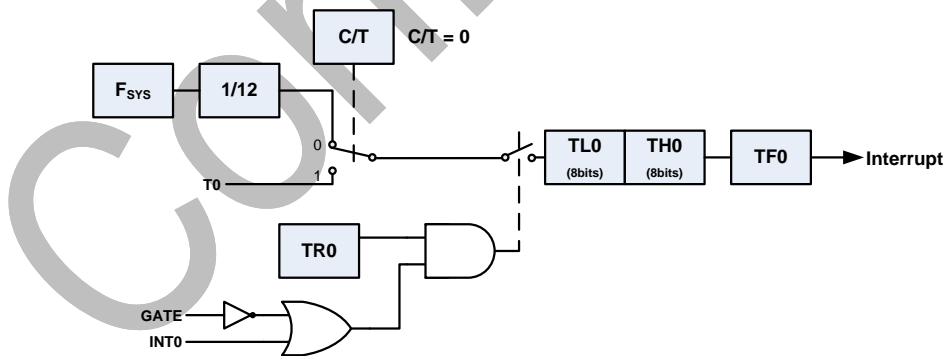


Figure 12. Timer0 Mode1

In mode2, TL0 of Timer0 is enabled as an 8-bit counter and TH0 reloads TL0 automatically. TF0 is set to '1' by overflowing of TL0. TH0 value retains the previous value regardless of the reloading. The operation of Timer1 is same as that of Timer0.

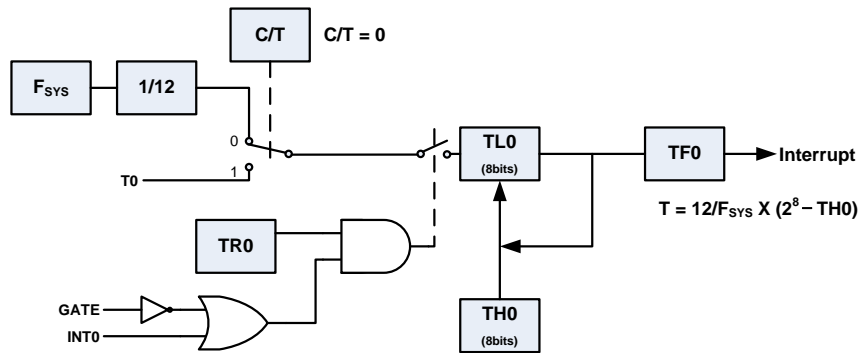


Figure 13. Timer0 Mode2

In Mode3, Timer0 uses TL0 and TH0 as an 8-bit timer respectively. In other words, it uses two counters. TL0 controls as the control signals of Timer0. TH0 is always used as a timer function and it controls as TR1 of Timer1. The overflow is stored in TF1. At this time, Timer1 is disabled and it retains the previous value.

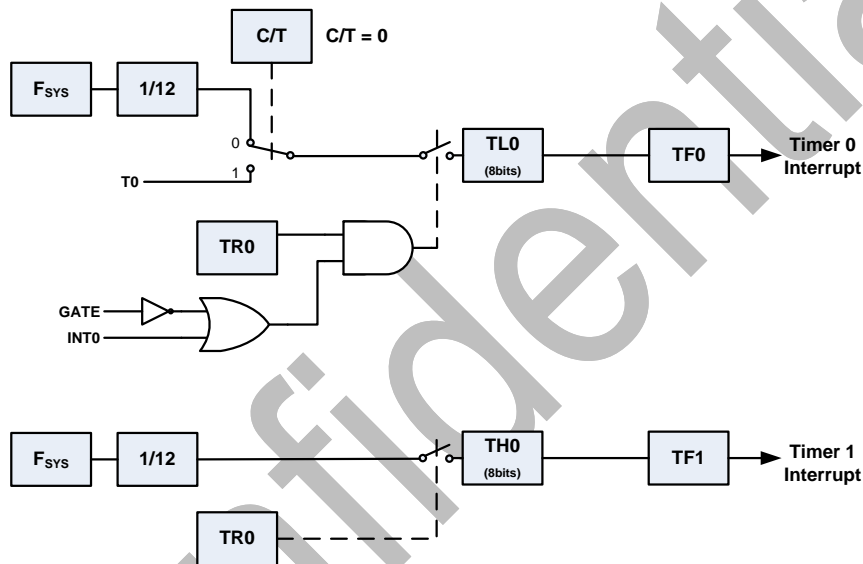


Figure 14. Timer0 Mode3

## 8.4. PWMs

The PWM is a user-programmable PWM and can also supports timer and counter controller features. Its use is to implement functions like Pulse Width Modulation (PWM), timer and counter facilities.

The following lists the main features of PWM core.

- 5 channel support
- 16-bit counter/timer facility
- Single-run or continues run of PTC counter
- Programmable PWM mode
- HI/LO Reference and Capture registers
- PWM/Timer/Counter functionalities can cause an interrupt to the CPU

$$T = \frac{f_{system}}{CNTR}$$

When operating in PWM mode, the PWM core generates binary signal with user programmable low and high periods.

When operating in timer/counter mode, the PWM core counts number of clock cycles of system clock. After reaching low and/or high reference, the PWM core can generate an interrupt. Input signal PWM pad can be used to capture value of the CNTR register into low and high capture registers.

When operating from the system clock, PTC\_GATE pin can be used to gate internal timer/counter circuitry. In both PWM and timer/counter modes, CNTR can run for a single cycle and it can automatically restart after each complete cycle. Cycle completes after reaching value in the LRC register. These two modes are called single-run and continuous-run.

### PWM Mode

To operate in PWM mode, HRC and LRC should be set with the value of low and high periods of the PWM output signal. HRC is number of clock cycles after reset of the CNTR when PWM output should go high. And LRC is number of clock cycles after reset of the CNTR when PWM output should go low.

CNTR can be reset with the hardware reset, bit CTRL[CNTRRST] or periodically when CTRL[SINGLE] bit is cleared. To enable PWM output driver, CTRL[OE] should be set. To enable continues operation, CTRL[SINGLE] should be cleared and CTRL[EN] should be set. If gate function is enabled, PWM periods can be automatically adjusted with the capture input. PWM output signal is controlled with the HRC and LRC, and these two registers can be set without software control with the PTC\_GATE pin signal.

Usually interrupts are enabled in timer/counter mode. This is done with the CTRL[INTE].

### Gate Feature

If system clock is used to increment CNTR, PTC\_GATE pin input signal can be used to gate the system clock and not increment the CNTR register. Which level of the PTC\_GATE pin has gating capability depends on value of the CTRL[NEC].

### Interrupt Feature

Whenever CNTR equals to the value of the HRC or LRC, an interrupt request can be asserted. This depends if CTRL[INTE] bit is set.

### Capture Feature

PWM pin input signal can be used to capture value of the current CNTR into HRC or LRC registers. Into which reference/capture register value is captured, depends on edge of the PWM pin input signal. On positive edge value is captured into HRC register and on negative edge value is captured into LRC register. In order to enable capture feature, CTRL[CAPTE] must be set.

### PWMx\_CNTR

CNTR register is the actual counter register. It is incremented at every counter/timer clock cycle. In order to count, CNTR must first be enabled with the CTRL[EN]. CNTR can be reset with the CTRL[RST]. CNTR can operate in either single-run mode or continues mode. Mode is selected with the CTRL[SINGLE].

**PWMx\_CNTRH(PWM CHx COUNTER REGISTER MSB PART, 0x2580(CH0), 0x2588(CH1), 0x2590(CH2), 0x2598(CH3), 0x25A0(CH4))**

Bit Field	Name	Descriptions	R/W	Reset Value
15:8	CNTR	MSB Part of CNTR register	R/W	0

**PWMx\_CNTRL(PWM CHx COUNTER REGISTER LSB PART, 0x2581(CH0), 0x2589(CH1), 0x2591(CH2), 0x2599(CH3), 0x25A1(CH4))**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	CNTR	LSB Part of CNTR register	R/W	0

**PWMx\_HRC**

HRC register is a second out of two reference/capture registers. It has two functions;

- In reference mode it is used to assert high PWM output or to generate an interrupt.
- In capture mode it captures CNTR value on high value of PWM pin input signal.

The HRC should have lower value than LRC. This is because PWM output goes first high and later low.

**PWMx\_HRCH (PWM CHx HIGH REF/CAP REGISTER, MSB Part, 0x2582(CH0), 0x258A(CH1), 0x2592(CH2), 0x259A(CH3), 0x25A2(CH4))**

Bit Field	Name	Descriptions	R/W	Reset Value
15:8	HRC	MSB Part of HRC register	R/W	0

**PWMx\_HRCL (PWM CH0 HIGH REF/CAP REGISTER, LSB Part, 0x2583(CH0), 0x258B(CH1), 0x2593(CH2), 0x259B(CH3), 0x25A3(CH4))**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	HRC	LSB Part of HRC register	R/W	0

**PWMx\_LRC**

LRC register is a first out of two reference/capture registers. It has two functions;

- In reference mode it is used to assert low PWM output or to generate an interrupt
- In capture mode it captures CNTR value on low value of PWM pin input signal

The LRC should have higher value than HRC. This is because PWM output goes high first and then low later.

**PWMx\_LRCH (PWM CHx LOW REF/CAP REGISTER, MSB Part, 0x2584(CH0), 0x258C(CH1), 0x2594(CH2), 0x259C(CH3), 0x25A4(CH4))**

Bit Field	Name	Descriptions	R/W	Reset Value
15:8	LRC	MSB Part of LRC register	R/W	0

**PWMx\_LRCL (PWM CHx LOW REF/CAP REGISTER, LSB Part, 0x2585(CH0), 0x258D(CH1), 0x2595(CH2), 0x259D(CH3), 0x25A5(CH4))**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	LRC	LSB Part of LRC register	R/W	0

**PWMx\_CTRL**

Control bits in CTRL register control operation of PWM core.

**PWMx\_CTRL (PWM CHx CONTROL REGISTER, 0x2586(CH0), 0x258E(CH1), 0x2596(CH2), 0x259E(CH3), 0x25A6(CH4))**

Bit Field	Name	Descriptions	R/W	Reset Value
7	INTE	Interrupt Enable	R/W	0
6	CAPTE	When set, PWM pin input signal can be used to capture CNTR into LRC or HRC registers. Into which reference/capture register capture occurs depends on edge of the PWM pin input signal. When cleared, capture function is masked.	R/W	0
5	CNTRRST	When set, CNTR is under reset. When cleared, normal operation of the counter is allowed.	R/W	0
4	SINGLE	When set, CNTR is not incremented anymore after it reaches value equal to the LRC value. When cleared, CNTR is restarted after it reaches value in the LCR register.	R/W	0
3	OE	The value of this bit is reflected on the PWM pin output signal. It is used to enable PWM output driver.	R/W	0
2	NEC	When set, PTC_GATE increments on negative edge and gates on low period. When cleared, ptc_ecgt increments on positive edge and gates on high period. This bit has effect only on 'gating' function of PTC_GATE .	R/W	0
1	GATE	Gate enable	R/W	0
0	EN	When set, CNTR can be incremented.	R/W	0

**PWM\_INTR (PWM INTERRUPT FLAG REGISTER, 0x257F)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:5	Reserved	-	-	-
4	PWM4INTR	PWM CH4 Interrupt flag.	R/W	0
3	PWM3INTR	PWM CH3 Interrupt flag.	R/W	0
2	PWM2INTR	PWM CH2 Interrupt flag.	R/W	0
1	PWM1INTR	PWM CH1 Interrupt flag.	R/W	0
0	PWM0INTR	PWM CH0 Interrupt flag.	R/W	0

## 8.5. Watchdog Timer

Watchdog Timer (WDT) monitors whether MCU is normally operating or not. If a problem is caused, it immediately resets MCU.

In fact, when a system does not clear WDT counter value, WDT considers that a problem is caused. Therefore, it automatically resets MCU. WDT is used when a program is not completed normally because a software error is caused in any environment such as electrical noise, unstable power, and static electricity.

When Power-up, the internal counter value of WDT is set to '0' and watchdog timer is



operated. If overflow is caused in the internal counter, system reset is caused. At this moment, timeout period is about 2.0 second. A user may not use WDT by setting ENB bit of WDTCON register. When WDT operates, an application program must clear CLR bit periodically to prevent a system from being reset.

The overflow interval can be set by DUR bits. The interval calculated as follows;

$$T = \frac{2^{DUR+1}}{f_{RTCCLK}}$$

To protect WDTCON register write access, special write sequence is required.

WDTCON ← 0x55 (write password 1)  
 WDTCON ← 0xAA (write password 2)  
 WDTCON ← (Control Value)

If the special sequence is not applied, it immediately resets MCU.

#### WDTCON (WATCHDOG TIMER CONTROL REGISTER, MCU SFR 0xD2)

Bit Field	Name	Descriptions	R/W	Reset Value
7	ENB	Watchdog Timer Enable Bar. Active Low	R/W	0
6	CLR	Watchdog Timer Clear. Auto Clear Bit. This bit clear Internal WDT Counter.	W/O	0
5	SYNCBUSY	Synch Busy. This bit indicates during WDT register update.	R/W	0
3:0	DUR	Watchdog Timer Duration	R/W	0xF

## 8.6. UART 0/1

Serial communication is categorized as synchronous mode or asynchronous mode in terms of its data transmission method. Synchronous mode is to transmit the data based on the standard clock pulse. Asynchronous mode is to transmit the data bit by arranging the baud rate of data bit each other without standard clock. That is, when a transmitter transmits the data as arranged frequency, a receiver read the data according to the arranged method previously.

The embedded MCU has UART0 and UART1 to enable two-way communication. These devices support asynchronous mode. The following registers are used to control UART. The baudrate can be set by following expression;

$$Baudrate = \frac{f_{system}}{XCR \times Divisor(16bits)}$$

#### RBR (UART0 RECEIVE BUFFER REGISTER, 0x2500)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	RBR	Read the received data	R/O	0x00

#### THR (UART0 TRANSMITTER HOLDING REGISTER, 0x2500)



Bit Field	Name	Descriptions	R/W	Reset Value
7:0	THR	This register stores the data to be transmitted. The address is the same as RBR register. When accessing this address, received data(RBR) is read and the data to be transmitted is stored.	W/O	0x00

#### DLL (UART0 DIVISOR LSB REGISTER, 0x2500)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	DLL	This register can be accessed only when DLAB bit in the LCR register is set to '1'. This register shares a 16-bit register with the DLM register occupying the lower 8 bits. This full 16-bit register is used to divide clock.	R/W	0x00

#### IER (UART0 INTERRUPT ENABLE REGISTER, 0x2501)

Bit Field	Name	Descriptions	R/W	Reset Value
7:4		Reserved		0
3	EDSSI	Enable MODEM Status Interrupt. When this field is set to '1', Modem status interrupt is enabled.	R/W	0
2	ELSI	Enable Receiver Line Status Interrupt.	R/W	0
1	ETBEI	Enable Transmitter Holding Register Empty Interrupt	R/W	0
0	ERBEI	Enable Received Data Available Interrupt	R/W	0

#### DLM (UART0 DIVISOR LATCH MSB REGISTER, 0x2501)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	DLM	This register can be accessed only when DLAB bit in the LCR register is set to '1'. This register shares a 16-bit register with the DLL register occupying the higher 8 bits. This full 16-bit register is used to divide clock.	R/W	0x00

#### IIR (UART0 INTERRUPT IDENTIFICATION REGISTER, 0x2502)

Bit Field	Name	Descriptions	R/W	Reset Value
7:4		Reserved	R/O	0
3:1	INTID	Interrupt Identification. Refer to the [Table 6].	R/O	0
0	PENDING	Shows whether the interrupt is pending or not. When this field is '0', the interrupt is pending.	R/O	1

Note: IIR register uses the same address as FCR register below. IIR register is read only

and FCR register is write-only.

**Table 6. UART0 Interrupt List**

INTID	Priority	Interrupt Type	Interrupt Source	Interrupt Control	Reset
011	1 <sup>st</sup>	Receiver Line Status	Parity, Overrun or Framing errors or Break Interrupt	Reading the LSR (Line Status Register).	Status
010	2 <sup>nd</sup>	Receiver Data available	FIFO trigger level reached	FIFO drops below trigger level	
110	2 <sup>nd</sup>	Timeout Indication	There is at least 1 character in the FIFO but no character has been input to the FIFO or read from it for the last 4 character times.	Reading from the FIFO (Receiver Buffer Register)	
001	3 <sup>rd</sup>	Transmitter Holding Register Empty	Transmitter Holding Register Empty	Writing to the Transmitter Holding Register or reading IIR	
000	4 <sup>th</sup>	Modem Status	CTS, DSR, RI or DCD	Reading the Modem register	status

**FCR (UART0 FIFO CONTROL REGISTER, 0x2502)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:6	URXFTRIG	Adjust the trigger level of Receiver FIFO. Interrupt occurs when FIFO receives the data byte based on this field value below. For example, when URFTRIG field is set to '3', interrupt does not occur until FIFO receives 14 byte. When FIFO receives 14 byte, interrupt occurs. 0: 1byte 1: 4 byte 2: 8 byte 3: 14 byte	W/O	3
5:3		Reserved	W/O	0
2	UTXFRST	When this field is set to '1', Transmitter FIFO is cleared and the circuits related to it are reset.	W/O	0
1	URXFRST	When this field is set to '1', Receiver FIFO is cleared and the circuits related to it are reset.	W/O	0
0		Reserved	W/O	0

**LCR (UART0 LINE CONTROL REGISTER, 0x2503)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	DLAB	Divisor Latch Access Enable.	R/W	0

		When this field is set to '1', Divisor register (DLM, DLL) can be accessed. When this field is set to '0', general register can be accessed.		
6	SB	Set Break. When this field is set to '1', serial output is to be '0' by force(break state)	R/W	0
5	SP	Stick Parity. When PEN and EPS is '1' while this field is set to '1', parity, which is generated as '0', is transmitted. In reception mode, it checks whether parity value is '0' or not.  When PEN is '1' and EPS is '0' while this field is set to '1', parity, which is generated as '1', is transmitted. In reception mode, it checks whether parity value is '1' or not.	R/W	0
4	EPS	Even Parity Enable. When this field is set to '1', parity value is determined to transfer '1' which is in even number. When this field is set to '0', parity value is determined to transfer '1' which is in odd number.	R/W	0
3	PEN	Parity Enable. When this field is set to '1', parity is calculated for the byte to be transmitted and transferred with it. In reception mode, checks parity. When this field is '0', parity is not generated.	R/W	0
2	STB	Number of Stop Bits. When this field is set to '1', 2 stop bit is used. When transmitting a word (character) of 5 bit length, 1.5 stop bit is used. When this field is '0', 1 stop bit is used.	R/W	0
1:0	WLS	Word Length Select. 0: 5bit Word 1: 6bit Word 2: 7bit Word 3: 8bit Word	R/W	3

#### LSR (UART0 LINE STATUS REGISTER, 0x2505)

Bit Field	Name	Descriptions	R/W	Reset Value
7	ERCVR	Error in Receiver Indicator. 1: At least one parity error, framing error or break indications have been received. The bit is cleared upon reading from the register. 0: Otherwise.	R/O	0
6	TEMT	Transmitter Empty indicator.	R/O	1

		1: Both the transmitter FIFO and transmitter shift register are empty. The bit is cleared when data is being written to the transmitter FIFO. '0' – Otherwise.		
5	THRE	Transmit FIFO is empty. 1: The transmitter FIFO is empty. Generates Transmitter Holding Register Empty interrupt. The bit is cleared when data is being written to the transmitter FIFO. 0: Otherwise.	R/O	1
4	BI	Break Interrupt (BI) indicator. 1: A break condition has been reached in the current character. The break occurs when the line is held in logic 0 for a time of one character (start bit + data + parity + stop bit). In that case, one zero character enters the FIFO and the UART waits for a valid start bit to receive next character. The bit is cleared upon reading from the register. Generates receiver Line Status interrupt. 1: No break condition in the current character.	R/O	0
3	FE	Framing Error (FE) indicator. 1: The received character at the top of the FIFO did not have a valid stop bit. Of course, generally, it might be that all the following data is corrupt. The bit is cleared upon reading from the register. Generates Receiver Line Status interrupt. 1: No framing error in the current character.	R/O	0
2	PE	Parity Error (PE) indicator. 1: The character that is currently at the top of the FIFO has been received with parity error. The bit is cleared upon reading from the register. Generates Receiver Line Status interrupt. 1: No parity error in the current character.	R/O	0
1	OE	Overrun Error (OE) indicator. 1: If the FIFO is full and another character has been received in the receiver shift register. If another character is starting to arrive, it will overwrite the data in the shift register but the FIFO will remain intact. The bit is cleared upon reading from the register. Generates Receiver Line Status interrupt. 0: No overrun state	R/O	0
0	DR	Data Ready (DR) indicator. 0: No characters in the FIFO. 1: At least one character has been	R/O	0

		received and is in the FIFO.		
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**XCR (UART0 DIVISOR LSB REGISTER, 0x2507)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	XCR	This register can be accessed only when DLAB bit in LCR register is set to '1'. This register consists of 8 bit register. XCR register with DLM, DLL registers used in baudrate generation.	R/W	0x10

**ECR (UART0 EXTRA FEATURE CONTROL REGISTER, 0x2505)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:3		Reserved.	W/O	0
2:0	ECR	Extra feature control register. 0: Default register access. 2: RX FIFO Interrupt level (RIL) register access enable. 5: TX FIFO level count (TLC) register and RX FIFO level count (RLC) register access enable.	W/O	0

**TLC (UART0 TX FIFO LEVEL COUNT REGISTER, 0x2503)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	TXLVLCNT	This register can be accessed when ECR register is set to '5'. This register indicates filled data size in the TX FIFO	R/O	0x00

**RIL (UART0 RX FIFO INTERRUPT LEVEL REGISTER, 0x2504)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	RXINTLVL	This register can be accessed when ECR register is set to '2'. When RIL register is set to zero value, the URXFTRIG field of FCR is valid. If RIL register is set to non-zero value, the receiver FIFO interrupt occurs when received bytes is greater than or equal to RIL register value.	R/W	0x00

**RLC (UART0 RX FIFO LEVEL COUNT REGISTER, 0x2504)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	RXLVLCNT	This register can be accessed when ECR register is set to '5'. This register indicates filled data size in the RX FIFO.	R/O	0x00

**VSPMUX (VOICE SOURCE PATH MUX CONTROL REGISTER, 0x277F)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:3		Reserved.	R/W	0
2:0	VSPMUX	when VSPMUX register set to '1'. UART0 FIFO size is changed 256 entry. Otherwise, UART0 FIFO size is 16 entry. The detailed information is in the Voice Part.	R/W	0

The following registers are to control UART1.

#### RBR (UART1 RECEIVE BUFFER REGISTER, 0x2510)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	RBR	Read the received data	R/O	0x00

#### THR (UART1 TRANSMITTER HOLDING REGISTER, 0x2510)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	THR	This register stores the data to be transmitted. The address is same as RBR register. By accessing this address, received data(RBR) can be read and the data to be transmitted can be stored.	W/O	0x00

#### DLL (UART1 DIVISOR LSB REGISTER, 0x2510)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	DLL	This register can be accessed only when DLAB bit in LCR register is set to '1'. This register consists of 16-bit register with DLM register and it is a lower 8 bit of 16-bit. This 16-bit register is used to divide clock.	R/W	0x00

#### IER (UART1 INTERRUPT ENABLE REGISTER, 0x2511)

Bit Field	Name	Descriptions	R/W	Reset Value
7:4		Reserved		0
3	EDSSI	Enable MODEM Status Interrupt. When this field is set to '1', Modem status interrupt is enabled.	R/W	0
2	ELSI	Enable Receiver Line Status Interrupt.	R/W	0
1	ETBEI	Enable Transmitter Holding Register Empty Interrupt	R/W	0
0	ERBEI	Enable Received Data Available Interrupt	R/W	0

#### DLM (UART1 DIVISOR LATCH MSB REGISTER, 0x2511)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	DLM	This register can be accessed only when DLAB bit in LCR register is set to '1'. This register consists of 16-bit register with DLL register and it is a higher 8 bit of 16-bit. This 16-bit register is used to divide clock.	R/W	0x00

### IIR (UART1 INTERRUPT IDENTIFICATION REGISTER, 0x2512)

Bit Field	Name	Descriptions	R/W	Reset Value
7:4		Reserved	R/O	0
3:1	INTID	Interrupt Identification. Refer to the [Table 7].	R/O	0
0	PENDING	Shows whether the interrupt is pending or not. When this field is '0', the interrupt is pending.	R/O	1

Note: IIR register uses the same address as FCR register below. IIR register is read only and FCR register is write-only.

Table 7. UART1 Interrupt List

INTID	Priority	Interrupt Type	Interrupt Source	Interrupt Control	Reset
011	1 <sup>st</sup>	Receiver Line Status	Parity, Overrun or Framing errors or Break Interrupt	Reading the LSR (Line Status Register).	Status
010	2 <sup>nd</sup>	Receiver Data available	FIFO trigger level reached	FIFO drops below trigger level	
110	2 <sup>nd</sup>	Timeout Indication	There is at least 1 character in the FIFO but no character has been input to the FIFO or read from it for the last 4 character times.	Reading from the FIFO (Receiver Buffer Register)	
001	3 <sup>rd</sup>	Transmitter Holding Register Empty	Transmitter Holding Register Empty	Writing to the Transmitter Holding Register or reading IIR	
000	4 <sup>th</sup>	Modem Status	CTS, DSR, RI or DCD	Reading the Modem status register	

### FCR (UART1 FIFO CONTROL REGISTER, 0x2512)

Bit Field	Name	Descriptions	R/W	Reset Value
7:6	URXFTRIG	Adjust the trigger level of Receiver FIFO. Interrupt occurs when FIFO receives the data byte based on this field's value below. For example, when URXFTRIG field is set to '3', interrupt does not occur	W/O	3



		until FIFO receives 14 bytes. When FIFO receives 14 byte, interrupt occurs. 0: 1byte 1: 4 byte 2: 8 byte 3: 14 byte		
5:3		Reserved	W/O	0
2	UTXFRST	When this field is set to '1', Transmitter FIFO is cleared and the circuits related to it are reset.	W/O	0
1	URXFRST	When this field is set to '1', Receiver FIFO is cleared and the circuits related to it are reset.	W/O	0
0		Reserved	W/O	0

### LCR (UART1 LINE CONTROL REGISTER, 0x2513)

Bit Field	Name	Descriptions	R/W	Reset Value
7	DLAB	Divisor Latch Access Enable. When this field is set to '1', Divisor register (DLM, DLL) can be accessed. When this field is set to '0', general register can be accessed.	R/W	0
6	SB	Set Break. When this field is set to '1', serial output is forced to be '0'(break state).	R/W	0
5	SP	Stick Parity. When PEN and EPS are '1' while this field set to '1', a parity of '0' is transmitted. In reception mode, it checks whether parity value is '0' or not. When PEN is '1' and EPS is '0' while this field is to '1', parity of '1', is transmitted. In reception mode, it checks whether parity value is '1' or not.	R/W	0
4	EPS	Even Parity Enable. When this field is set to '1', parity value is even. When set to '0', parity value is odd.	R/W	0
3	PEN	Parity Enable. When this field is set to '1', parity is calculated for the byte to be transmitted and transferred with it. In reception mode, checks parity. When this field is '0', parity is not generated.	R/W	0
2	STB	Number of Stop Bits. When this field is set to '1', 2 stop bit is used. When transmitting a word (character) of 5 bit length, 1.5 stop bit is used. When this field is '0', 1 stop bit is used.	R/W	0
1:0	WLS	Word Length Select. 0: 5bit Word	R/W	3



		1: 6bit Word 2: 7bit Word 3: 8bit Word		
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**LSR (UART1 LINE STATUS REGISTER, 0x2515)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	ERCVR	Error in Receiver Indicator.  1: At least one parity error, framing error or break indications have been received. The bit is cleared upon reading from the register. 0: Otherwise.	R/O	0
6	TEMT	Transmitter Empty indicator.  1: Both the transmitter FIFO and transmitter shift register are empty. The bit is cleared when data is being written to the transmitter FIFO. '0': Otherwise.	R/O	1
5	THRE	Transmit FIFO is empty.  1: The transmitter FIFO is empty. Generates Transmitter Holding Register Empty interrupt. The bit is cleared when data is being written to the transmitter FIFO. 0: Otherwise.	R/O	1
4	BI	Break Interrupt (BI) indicator.  1: A break condition has been reached in the current character. The break occurs when the line is held in logic 0 for a time of one character (start bit + data + parity + stop bit). In that case, one zero character enters the FIFO and the UART waits for a valid start bit to receive next character. The bit is cleared upon reading from the register. Generates receiver Line Status interrupt. 0: No break condition in the current	R/O	0

		character.		
3	FE	<p>Framing Error (FE) indicator.</p> <p>1: The received character at the top of the FIFO did not have a valid stop bit. Of course, generally, it might be that all the following data is corrupt. The bit is cleared upon reading from the register. Generates Receiver Line Status interrupt.</p> <p>0: No framing error in the current character.</p>	R/O	0
2	PE	<p>Parity Error (PE) indicator.</p> <p>1: The character that is currently at the top of the FIFO has been received with parity error. The bit is cleared upon reading from the register. Generates Receiver Line Status interrupt.</p> <p>0: No parity error in the current character.</p>	R/O	0
1	OE	<p>Overrun Error (OE) indicator.</p> <p>1: If the FIFO is full and another character has been received in the receiver shift register. If another character is starting to arrive, it will overwrite the data in the shift register but the FIFO will remain intact. The bit is cleared upon reading from the register. Generates Receiver Line Status interrupt.</p> <p>0: No overrun state</p>	R/O	0
0	DR	<p>Data Ready (DR) indicator.</p> <p>0: No characters in the FIFO.</p> <p>1: At least one character has been received and is in the FIFO.</p>	R/O	0

### XCR (UART1 CLOCK DIVISOR REGISTER, 0x2517)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	XCR	This register can be accessed only when DLAB bit in LCR register is set to '1'. This register consists of 8 bit register. XCR register with DLM and DLL registers used in UART baudrate generation.	R/W	0x10

**ECR (UART1 EXTRA FEATURE CONTROL REGISTER, 0x2515)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:3		Reserved.	W/O	0
2:0	ECR	Extra feature control register. 0: Default register access. 2: RX FIFO Interrupt level (RIL) register access enable. 5: TX FIFO level count (TLC) register and RX FIFO level count (RLC) register access enable.	W/O	0

**TLC (UART1 TX FIFO LEVEL COUNT REGISTER, 0x2513)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	TXLVLCNT	This register can be accessed when ECR register is set to '5'. This register indicates filled data size in the TX FIFO	R/O	0x00

**RIL (UART1 RX FIFO INTERRUPT LEVEL REGISTER, 0x2514)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	RXINTLVL	This register can be accessed when ECR register is set to '2'. when RIL register is set to zero value, the URXFTRIG field of FCR is valid. If RIL register is set to non-zero value, the receiver FIFO interrupt occurs when received bytes is greater than or equal to RIL register value.	R/W	0x00

**RLC (UART1 RX FIFO LEVEL COUNT REGISTER, 0x2514)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	RXLVLCNT	This register can be accessed when ECR register is set to '5'. This register indicates filled data size in the RX FIFO.	R/O	0x00

**VSPMUX (VOICE SOURCE PATH MUX CONTROL REGISTER, 0x277F)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:3		Reserved.	R/W	0
2:0	VSPMUX	when VSPMUX register set to '2'. Otherwise, UART1 FIFO size is 16 entry. The detailed information is in the Voice Part.	R/W	0

### 8.7. SPI MASTER/SLAVE

During an SPI transmission, data is simultaneously transmitted (shifted out serially) and received (shifted in serially). The operation is different in either Master mode or Slave mode

In the Master mode, the data transmission is done by writing to the SPDR (SPI Data Register, 0x2542).

After transmission, data reception is initiated by a byte transmitted to the Slave device from the Master SPI clock. When the SPI interrupt occurs, the value of the SPDR register becomes the received data from the SPI slave device. Even though the SPDR TX and RX have the same address, no data collision occurs because the processes of writing and reading data happen sequentially.

In the Slave mode, the data must be ready in the SPDR when the Master calls for it. Data transmission is accomplished by writing to the SPDR before the SPI clock is generated by the Master. When the Master generates the SPI clock, the data in the SPDR of the Slave is transferred to the Master. If the SPDR in the Slave is empty, no data exchange occurs. Data reception is done by reading the SPDR when the next SPI interrupt occurs.

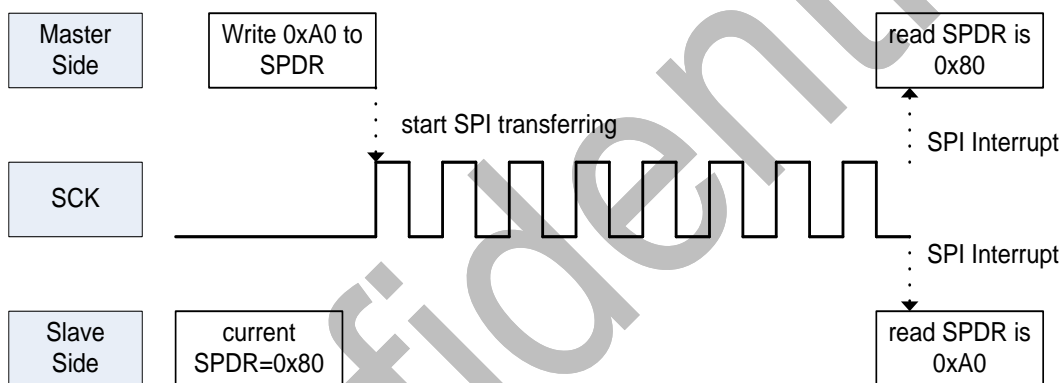


Figure 15. SPI Data Transfer

#### SPCR (SPI CONTROL REGISTER, 0x2540)

Bit Field	Name	Descriptions	R/W	Reset Value
7	SPIE	SPI Interrupt Enable. When this field is set to '1', SPI interrupt is enabled.	R/W	0
6	SPE	SPI Enable. When this field is set to '1', SPI is enabled.	R/W	0
5		Reserved		0
4	MSTR	Master Mode Select. When this field is set to '1', a Master mode is selected.	R/W	1
3	CPOL	Clock Polarity. If there is no data transmission while this field is set to '0', SCK pin retains '0'. If there is no data transmission while this field is set to '1', SCK pin retains '1'. This field is used to set the clock and	R/W	0

		data between a Master and Slave with CPHA field. Refer to the below for a more detailed explanation.		
2	CPHA	Clock Phase. This field is used to set the clock and data between a Master and Slave with CPOL field.	R/W	0
1:0	SPR	SPI Clock Rate Select. With ESPR field in SPER register(0x2543), selects SPI clock(SCK) rate when the device is configured as a Master. Refer to the ESPR field below.	R/W	0

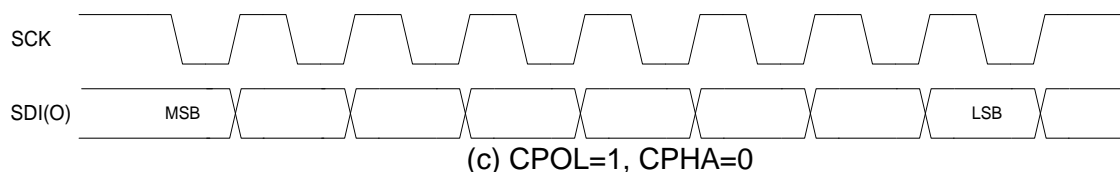
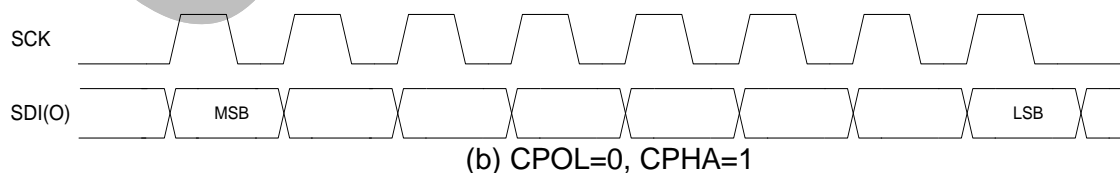
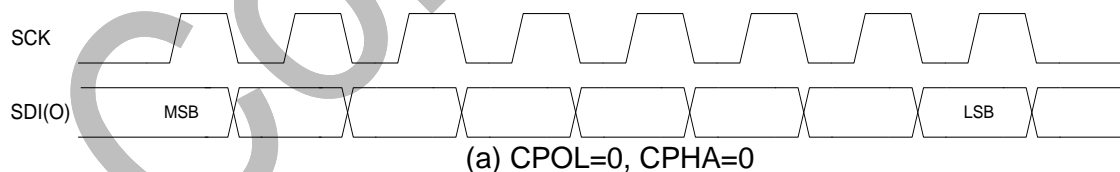
There are four methods of data transfer based on the settings of CPOL and CPHA. Polarity of SPI serial clock(SCK) is determined by CPOL value and it determines whether SCK activates high or low.

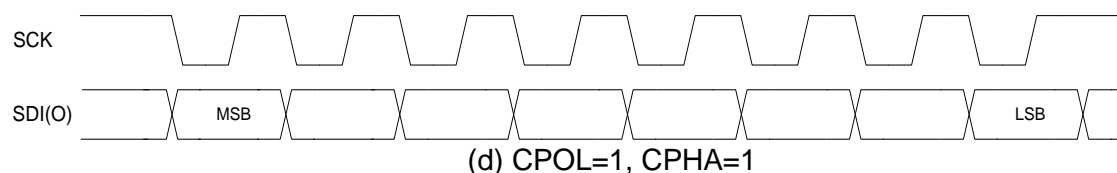
If CPOL value is '0', SCK pin retains '0' during no data transmission. If CPOL value is '1', SCK pin retains '1' during no data transmission. CPHA field determines the format of data to be transmitted.

The table below describes the clock polarity and the data transition timing.

CPOL	CPHA	SCK when idle	Data Transition Timing
0	0	Low	Falling Edge of SCK
0	1	Low	Rising Edge of SCK
1	0	High	Rising Edge of SCK
1	1	High	Falling Edge of SCK

The following describes this block when slave mode is selected. When the values of CPOL and CPHA are the same, (a) and (b) below, output data is changed at the falling edge of SCK. Input data is captured at the rising edge of SCK. When the CPOL and CPHA values are different, (b) and (c) below, output data is changed at the rising edge of received SCK. Input data is captured at the falling edge of SCK.



**SPSR (SPI STATUS REGISTER, 0x2541)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	SPIF	SPI Interrupt Flag. When SPI interrupt occurs, this field is set to '1'. Set whenever data transmission is finished and it can be cleared by software.	R/W	0
6	WCOL	Write Collision. This field is set to '1' when writing data to the SPDR register while SPITX FIFO is full. It can be cleared by software.	R/W	0
5:4		Reserved		0
3	WFFUL	Write FIFO Full. This field is set to '1' when Write FIFO is full. This field is read only.	R/O	0
2	WFEMPTY	Write FIFO Empty. This field is set to '1' when Write FIFO is cleared. This field is read only.	R/O	1
1	RFFUL	Read FIFO Full. This field is set to '1' when Read FIFO is full. This field is read only.	R/O	0
0	RFEMPTY	Read FIFO Empty. This field is set to '1' when Read FIFO is cleared. This field is read only.	R/O	1

**SPDR (SPI DATA REGISTER, 0x2542)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	SPDR	This register is read/write buffer.	R/W	-

**SPER (SPI E REGISTER, 0x2543)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:6	ICNT	Interrupt Count. This field indicates the number of byte to transmit. SPIF bit is set to '1' whenever each byte is transmitted.	R/W	0
5:2		Reserved		0
1:0	ESPR	Extended SPI Clock Rate Select. With SPR field in SPCR Register (0x2540), this field selects SPI	R/W	2

		clock(SCK) rate when a device is configured as a Master.																												
		<table border="1"> <thead> <tr> <th>{ESPR, SPR}</th> <th>(System Clock Divider)</th> </tr> </thead> <tbody> <tr><td>0000</td><td>Reserved</td></tr> <tr><td>0001</td><td>Reserved</td></tr> <tr><td>0010</td><td>8</td></tr> <tr><td>0011</td><td>32</td></tr> <tr><td>0100</td><td>64</td></tr> <tr><td>0101</td><td>16</td></tr> <tr><td>0110</td><td>128</td></tr> <tr><td>0111</td><td>256</td></tr> <tr><td>1000</td><td>512</td></tr> <tr><td>1001</td><td>1024</td></tr> <tr><td>1010</td><td>2048</td></tr> <tr><td>1011</td><td>4096</td></tr> </tbody> </table>	{ESPR, SPR}	(System Clock Divider)	0000	Reserved	0001	Reserved	0010	8	0011	32	0100	64	0101	16	0110	128	0111	256	1000	512	1001	1024	1010	2048	1011	4096		
{ESPR, SPR}	(System Clock Divider)																													
0000	Reserved																													
0001	Reserved																													
0010	8																													
0011	32																													
0100	64																													
0101	16																													
0110	128																													
0111	256																													
1000	512																													
1001	1024																													
1010	2048																													
1011	4096																													
		* ESPR field : high bit SPR field: low bit																												

The value of ESPR and SPR is used to divide system clock to generate SPI clock (SCK). For example, if the value of ESPR and SPR is '0010' and system clock is 8MHz, SPI clock (SCK) is 1MHz.

#### VSPMUX (VOICE SOURCE PATH MUX CONTROL REGISTER, 0x277F)

Bit Field	Name	Descriptions	R/W	Reset Value
7:3		Reserved.	R/W	0
2:0	VSPMUX	When VSPMUX register set to '3'. SPI FIFO size is changed 256 entries. Otherwise, SPI FIFO size is 16 entries. The detailed information is in the Voice Part.	R/W	0

### 8.8. I2C MASTER/SLAVE

TBD

## 8.9. IR(Infra-Red) Modulator

Embedded IR Modulator can support NEC PPM (Pulse Position Modulation) format transfer. The carrier duration and duty rate can be set by PPM\_TCCNT, PPM\_HCCNT. The data bit generation and the duty rate are set by PPM\_T0CNT, PPM\_H0CNT for bit pattern 0, and by PPM\_T1CNT, PPM\_H1CNT for bit pattern 1. The bit generation clock is generated by CDIV divisor.

$$\text{Carrier\_Freq} = \frac{f_{\text{system}}}{\text{TCCNT}}$$

$$\text{Carrier\_Duty} = \frac{\text{HCCNT}}{\text{TCCNT}}$$

$$\text{Bit0\_Duration} = \frac{\text{T0CNT} * \text{CDIV}}{f_{\text{system}}}$$

$$\text{Bit0\_Duty} = \frac{\text{H0CNT}}{\text{T0CNT}}$$

$$\text{Bit1\_Duration} = \frac{\text{T1CNT} * \text{CDIV}}{f_{\text{system}}}$$

$$\text{Bit1\_Duty} = \frac{\text{H1CNT}}{\text{T1CNT}}$$

### LCODE (PPM LEADER CODE REGISTER, 0x27A0)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	LCODE	This register is read/write buffer.	R/W	0x0F

### PPM\_SCODE (PPM STOP CODE REGISTER, 0x27A1)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	SCODE	This register is read/write buffer.	R/W	0x00

### PPM\_CC CODE (PPM CUSTOM CODE REGISTER, 0x27A2)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	CCODE	This register is read/write buffer.	R/W	0x00

### PPM\_CCODB (PPM CUSTOM CODE BAR REGISTER, 0x27A3)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	CCODB	This register is read/write buffer.	R/W	0xFF

### PPM\_DCODE (PPM DATA CODE REGISTER, 0x27A4)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	CCODE	This register is read/write buffer.	R/W	0x00



**PPM\_DCODB (PPM DATA CODE BAR REGISTER, 0x27A5)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	CCODB	This register is read/write buffer.	R/W	0xFF

**PPM\_CTL (PPM CONTROL REGISTER, 0x27A6)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	EN	This register is read/write buffer.	R/W	0
6	DONE	TX Done.	R/O	0
5	OE	Output Pin Enable	R/W	0
4	CONT	CONT generation	R/W	0
3	CPCC	Copy Custom Code Bar from PPM_CCODE register value	R/W	1
2	IVCC	Invert PPM_CCODE when CPCC=1	R/W	1
1	CPDC	Copy Custom Code Bar from PPM_DCODE register value	R/W	1
0	IVDC	Invert PPM_DCODE when CPDC=1	R/W	1

**PPM\_POSST (PPM DATA START POSITION REGISTER, 0x27A7)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	POSST	TX Start Bit Position	R/W	0x08

**PPM\_POSSP (PPM DATA STOP POSITION REGISTER, 0x27A8)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	POSSP	TX Stop Bit Position	R/W	0x29

**PPM\_TCCNT0 (PPM CARRIER DURATION COUNTER REGISTER, 0x27A9)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	TCCNT	PPM Carrier Duration Generation Counter. LSB Part	R/W	0x4A

**PPM\_TCCNT1 (PPM CARRIER DURATION COUNTER REGISTER, 0x27AA)**

Bit Field	Name	Descriptions	R/W	Reset Value
15:8	TCCNT	PPM Carrier Duration Generation Counter. LSB Part	R/W	0x03

**PPM\_HCNT0 (PPM CARRIER HIGH COUNTER REGISTER, 0x27AB)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	HCNT	PPM Carrier High Duration Counter. LSB Part	R/W	0x18

**PPM\_HCNT1 (PPM CARRIER HIGH COUNTER REGISTER, 0x27AC)**

Bit Field	Name	Descriptions	R/W	Reset Value

15:8	HCCNT	PPM Carrier High Duration Counter. MSB Part.	R/W	0x01
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**PPM\_T0CNT (PPM BIT0 DURATION COUNTER REGISTER, 0x27AD)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	T0CNT	PPM Data Bit Pattern 0 Duration Counter	R/W	0x20

**PPM\_T1CNT (PPM BIT1 DURATION COUNTER REGISTER, 0x27AE)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	T1CNT	PPM Data Bit Pattern 1 Duration Counter	R/W	0x40

**PPM\_H0CNT (PPM DATA CODE BAR REGISTER, 0x27AF)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	H0CNT	PPM Data Bit Pattern 0 High Duration Counter	R/W	x010

**PPM\_H1CNT (PPM DATA CODE BAR REGISTER, 0x27B0)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	H1CNT	PPM Data Bit Pattern 1 High Duration	R/W	0x10

**PPM\_CDIV0 (PPM DATA BAUDRATE DIVISOR REGISTER, 0x27B1)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	CDIV0	PPM Data Baud-rate Generate Divisor. LSB Part	R/W	0x65

**PPM\_CDIV1 (PPM DATA BAUDRATE DIVISOR REGISTER, 0x27B2)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	CDIV1	PPM Data Baud-rate Generate Divisor. MSB Part	R/W	0x04

## 8.10. VOICE

A voice function includes the following:

- I2S Interface
- Voice Encoder/Decoder (u-law / a-law / ADPCM)
- Voice FIFO
- DMA

The data generated through an external ADC is input to the voice block in the MG2470 via an I2S interface. Data received via I2S is compressed at the voice encoder, and stored in the Voice TXFIFO. The data is then transferred to the MAC TX FIFO through DMA operation and finally transmitted through the PHY layer.

By contrast, received data in the MAC RX FIFO is transferred to the Voice RXFIFO and decompressed in the voice decoder. It is finally transferred to an external DAC via I2S interface.

I2S is commonly used for transferring/receiving voice data. As well, voice data can be transferred or received via SPI or UART interface as well.

Voice encoder/decoder supports u-law, a-law and ADPCM methods. If the voice encoder/decoder function is not needed, it can be bypassed.

### 8.10.1. I2S

In I2S interface, data is transferred MSB first from the left channel, and then from the right channel. There are two ways to send data via I2S TX: writing data to the register by software, or by hardware. This is enabled by using POP field in STXMODE (0x252d). Similarly, there are two ways to receive data via I2S RX: the first is reading the register by software, and the other is by the PUSH field in SRXMODE (0x253d).

There are four methods in I2S interface as follows.

- I2S mode
- Left Justified mode
- Right Justified mode
- DSP mode

In I2S mode, left channel data is transferred in order. When left channel data is transferred, LRCK value is '0' and when right channel data is transferred, LRCK value is 0. Transferred data and LECK is changed at the falling edge. Refer to the (a) below.

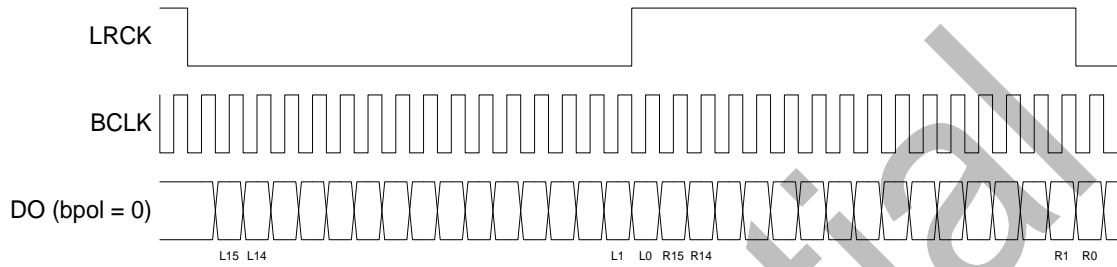
In Left Justified mode, left channel data is transferred whenever LRCK=1 and right channel data is transferred, whenever LRCK=0. LRCK is changed at the falling edge of BCLK. Transferred data is changed at the rising edge of BCLK. Refer to the (b) below.

In Right Justified mode, left channel data allows last LSB to be output before LRCK value goes to '0' and right channel data allows last LSB to be output before LRCK value goes to '1'. LRCK value is changed at the falling edge of BCLK. Output data is changed at the rising edge of BCLK. Refer to the (c) below.

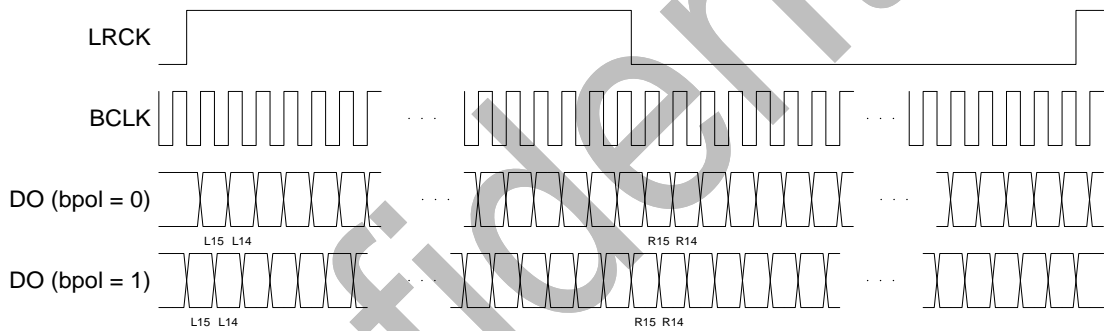
In DSP mode, after LRCK outputs to '1' for one period of BCLK, it goes to '0'. After that, left channel data is outputted and then right channel data is outputted. LRCK value is changed

at the falling edge of BCLK. Output data is changed at the rising edge of BCLK. Refer to the (d) below.

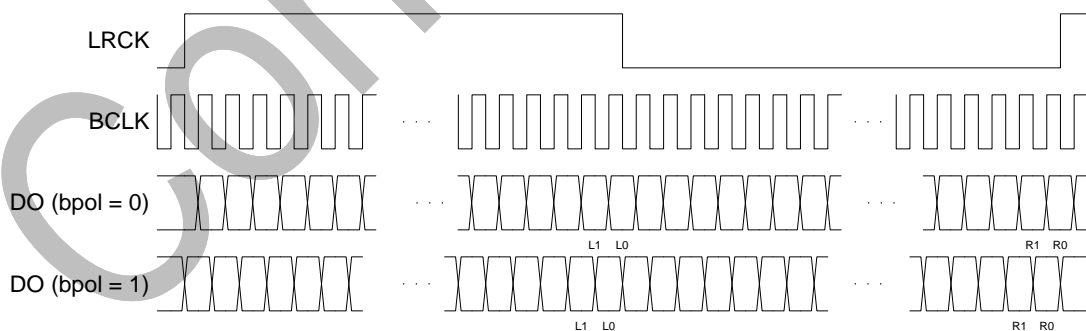
The following shows the interface method for each mode and I2S TX block is selected as Master. The setting of register is as follows. MS field in STXAIC (0x2528) register is set to '1'. WL field is set to '0'(The data of left and right channel represents 16-bit). Other fields are set to '0'. In ISP mode, BPOL field in STXMODE (0x252D) register is set to '0'. In other modes, BPOL field in STXMODE (0x252D) register is set to '0' or '1' respectively.



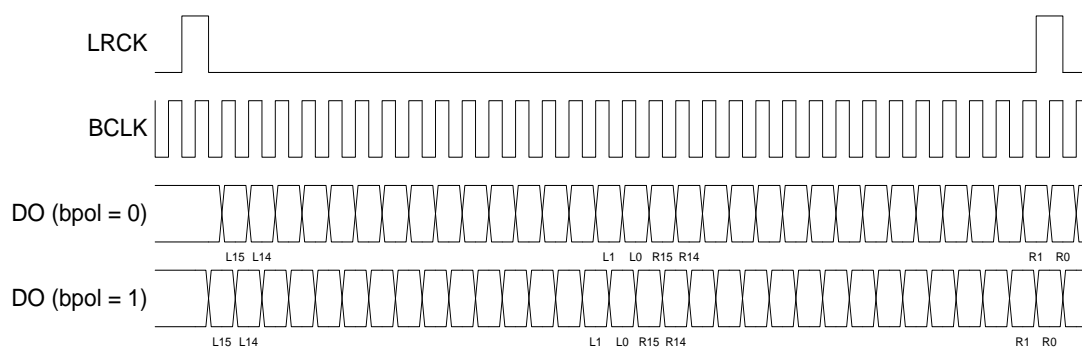
(a) I2S Mode



(b) Left Justified Mode



(c) Right Justified Mode



(d) DSP Mode

Figure 16. Four Methods in I2S Interface

**STXAIC (I2S TX INTERFACE CONTROL REGISTER, 0x2528)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	MS	When this field is set to '1', Master mode is configured. When this field is set to '0', Slave mode is configured. Any device can act as the system master by providing the necessary clock signals. A slave will usually derive its internal clock signal from an external clock input.	R/W	1
6:5	FMT	Four modes of operation determined by the value of this field below. 0: I2S mode 1: Left Justified mode 2: Right Justified mode 3: DSP mode	R/W	2
4:3	WL	Word Length. This field indicates the number of bits per channel. 0: 16 bit 1: 20 bit 2: 24 bit 3: 32 bit	R/W	0
2	LRSWAP	Left/Right Swap. When this field is set to '1', the order of the channel for transmitting data is changed. In other words, the data in a right channel is transmitted first.	R/W	0
1	FRAMEP	When this field is set to '1', the polarity of LRCK is changed. For example, in Left Justified mode, the left channel data is outputted when LRCK=1 and the right channel data is outputted when LRCK=0. However, when this field is set to '1', the right channel data is outputted when LRCK=1 and the left channel data is outputted when LRCK=0.	R/W	0
0	BCP	When this field is set to '1', the polarity of BCLK(Bit Clock) is changed.	R/W	0

		Clock edge, which allows the data change, is changed.		
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**STXSDIV (I2S TX SYSTEM CLOCK DIVISOR REGISTER, 0x252A)**

Bit Field	Name	Descriptions	R/O	Reset Value
7:0	STXSDIV	This register sets the value for dividing a system clock to generate MCLK. The equation is as follows: $MCLK = \text{System Clock} / (2 \times \text{STXSDIV})$ When this field is '0', MCLK is not generated.	R/O	0x00

**STXMDIV (I2S TX MCLK DIVISOR REGISTER, 0x252B)**

Bit Field	Name	Descriptions	R/O	Reset Value
7:0	STXMDIV	This register sets the value for dividing MCLK to generate BCLK. When STXSDIV register value is '1', $BCLK = MCLK / \text{STXMDIV}$ . When STXSDIV register value is greater than 2, $BCLK = MCLK / (2 \times \text{STXMDIV})$ . When this register value is '0', BCLK is not generated.	R/O	0x00

**STXBDIV (I2S TX BCLK DIVISOR REGISTER, 0x252C)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	STXBDIV	This register sets the value for dividing BCLK to generate LRCK. When FMT field in STXAIC(0x2528) register is '0','1','2', $LRCK = BCLK / (2 \times \text{STXBDIV})$ . When FMT field in STXAIC(0x2528) register is '3', $LRCK = BCLK / \text{STXBDIV}$ . When this register value is '0', LRCK is not generated.	R/W	0x00

**STXMODE (I2S TX MODE REGISTER, 0x252D)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	CSHR	This field is meaningful when I2STX block acts in a Slave mode. When this field is set to '1', I2S TX block shares the clock of I2S RX block. In other words, the MCLK of the I2S RX block is input to the MCLK of the I2S TX block and BCLK of I2S RX block is input to the BCLK of I2S TX block. As well, LRCK of I2S RX block is input to the	R/W	1

		LRCK of I2S TX block.		
6	MPOL	This field determines the polarity of MCLK. When this field is '0', MCLK signal retains '1'. When this field is '1', MCLK signal retains '0'.	R/W	1
5	BPOL	This field indicates the relationship between BCLK and LRCK. When this field is set to '0', LRCK value is changed at the falling edge of BCLK. When this field is set to '1', LRCK value is changed at the rising edge of BCLK.	R/W	1
4	B16	This field determines bit width to transfer data in voice block to I2S block. When this field is set to '1', data is transferred by 16-bit data format to I2S block. When this field is set to '0', data is transferred by 8-bit data format to I2S block.	R/W	1
3	POP	When this field is set to '1', data is transferred to I2S block. When this field is set to '0', data is not transferred to I2S block.	R/W	1
2:1	MODE	This field sets the mode of transferred data. 0: BLK Mode. Transfer a '0'. 1: MRT Mode. Only the data in Right channel is transferred.( '0' is transferred in Left channel) 2: MLT Mode. Only the data in Left channel is transferred.( '0' is transferred in Right channel) 3: STR Mode. All data in Left or Right channel are transferred.	R/W	3
0	CLKENA	Clock Enable. When this field is set to '1', I2S TX is enabled.	R/W	0

### SRXAIC (I2S RX INTERFACE CONTROL REGISTER, 0x2538)

Bit Field	Name	Descriptions	R/W	Reset Value
7	MS	When this field is set to '1', Master mode is configured. When this field is set to '0', Slave mode is configured. Any device can act as the system master by providing the necessary clock signals. A slave will usually derive its internal clock signal from an external clock input.	R/W	1

6:5	FMT	Four modes determined by the value of this field below. 0: I2S mode 1: Left Justified mode 2: Right Justified mode 3: DSP mode	R/W	2
4:3	WL	Word Length. This field indicates the number of bit per each channel. 0: 16 bit 1: 20 bit 2: 24 bit 3: 32 bit	R/W	0
2	LRSWAP	Left/Right Swap. When this field is set to '1', the order of the channel for transmitting data is changed. In other words, the data in a right channel is transmitted first.	R/W	0
1	FRAMEP	When this field is set to '1', the polarity of LRCK is changed, in Left Justified mode(FMT=1), data is stored in the left channel when LRCK=1 and data is stored in the right channel when LRCK=0. However, when this field is set to '1', data is stored in the right channel when LRCK=1 and the data is stored in the left channel when LRCK=0.	R/W	0
0	BCP	When this field is set to '1', the polarity of BCLK(Bit Clock) is changed. Clock edge, which allows the data change, is changed.	R/W	0

#### SRXSDIV (I2S RX SYSTEM CLOCK DIVISOR REGISTER, 0x253A)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	SRXSDIV	This register sets the value for dividing a system clock to generate MCLK. The equation is as follows: $MCLK = \text{System Clock} / (2 \times \text{SRXSDIV})$ When this field is '0', MCLK is not generated.	R/W	0x00

#### SRXMDIV (I2S RX MCLK DIVISOR REGISTER, 0x253B)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	SRXMDIV	This register sets the value for dividing MCLK to generate BCLK. When SRXSDIV register value is '1', $BCLK = MCLK / \text{SRXMDIV}$ . When SRXSDIV register value is greater than 2, $BCLK = MCLK / (2 \times \text{SRXMDIV})$ .	R/W	0x00



		When this register value is '0', BCLK is not generated.		
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**SRXBDIV (I2S RX BCLK DIVISOR REGISTER, 0x253C)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	SRXBDIV	This register sets the value for dividing BCLK to generate LRCK. When FMT field in SRXAIC(0x2528) register is '0','1','2', $LRCK = BCLK/(2(SRXBDIV))$ . When FMT field in SRXAIC(0x2528) register is '3', $LRCK = BCLK/SRXBDIV$ . When this register value is '0', LRCK is not generated.	R/W	0x00

**SRXMODE (I2S RX MODE REGISTER, 0x253D)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	CSHR	This field is meaningful when I2SRX block acts in a Slave mode. When this field is set to '1', I2S RX block shares the clock of I2S TX block. In other words, MCLK of I2S TX block is input to the MCLK of I2S RX block and BCLK of I2S TX block is input to the BCLK of I2S RX block. As well, LRCK of I2S TX block is input to the LRCK of I2S RX block.	R/W	0
6	MPOL	This field determines the polarity of MCLK. When this field is '0', MCLK signal retains '1'. When this field is '1', MCLK signal retains '0'.	R/W	1
5	BPOL	This field indicates the relationship between BCLK and LRCK. When this field is set to '0', LRCK value is changed at the falling edge of BCLK. When this field is set to '1', LRCK value is changed at the rising edge of BCLK.	R/W	1
4	B16	This field determines bit width to transfer data received from external ADC via I2S interface to voice block. When this field is set to '1', data is transferred by 16-bit data format to voice block. When this field is set to '0', data is transferred by 8-bit data format to voice block.	R/W	1
3	PUSH	When this field is set to '1', data received from external ADC via I2S interface is transferred to voice block. When this field is set to '0', data received	R/W	1

		from external ADC via I2S interface is not transferred to voice block.		
2:1	MODE	This field sets the mode of transferred data. 0: BLK Mode. Transfer a '0'. 1: MRT Mode. Only the data in Right channel is transferred.( '0' is transferred in Left channel) 2: MLT Mode. Only the data in Left channel is transferred.( '0' is transferred in Right channel) 3: STR Mode. All data in Left or Right channel are transferred.	R/W	3
0	CLKENA	Clock Enable. When this field is set to '1', I2S RX is enabled.	R/W	0

### 8.10.2. VOICE ENCODER/DECODER

MG2470 includes three voice encoder/decoder algorithms.

- $\mu$ -law
- a-law
- ADPCM

The  $\mu$ -law algorithm is a companding algorithm primarily used in the digital telecommunication systems of North America and Japan. As with other companding algorithms, its purpose is to reduce the dynamic range of an audio signal. In the analog domain this can increase the signal-to-noise ratio (SNR) achieved during transmission and in the digital domain, it can reduce the quantization error (hence increasing signal to quantization noise ratio). These SNR improvements can be traded for reduced bandwidth and equivalent SNR instead.

The a-law algorithm is a standard companding algorithm used in European digital communications systems to optimize/modify the dynamic range of an analog signal for digitizing.

The a-law algorithm provides a slightly larger dynamic range than the  $\mu$ -law at the cost of worse proportional distortion for small signals.

Adaptive DPCM (ADPCM) is a variant of DPCM (Differential (or Delta) pulse-code modulation) that varies the size of the quantization step, to allow further reduction of the required bandwidth for a given signal-to-noise ratio. DPCM encodes the PCM values as differences between the current and the previous value. For audio this type of encoding reduces the number of bits required per sample by about 25% compared to PCM.

In order to control voice encoder/decoder, there are several registers. This section describes the major commonly used registers. For more detailed information, please contact RadioPulse Inc.

#### ENCCTL (VOICE ENCODER CONTROL REGISTER, 0x2745)

Bit Field	Name	Descriptions	R/W	Reset Value
7:6		Reserved	R/W	0
5	B16	When the bit width of data received to voice encoder is 16-bit, set this field to '1'. When it is 8-bit, set this field to '0'.	R/W	0
4	MUT	Mute Enable. When this field is set to '1', the Mute function is enabled. ENCMUT1 and ENCMUT0 values are input to the voice encoder block.	R/W	0
3:2	SEL	Encoder Select. Selects voice encoder algorithm. 0: No Encoding 1: $\mu$ -law 2: a-law 3: ADPCM	R/W	0
1	INI	Encoder Initialize. When this field is set to '1', the pointer in voice encoder is initialized. This field cannot be read.	W	0
0	ENA	Encoder Enable. When this field is set to '1', voice encoder acts.	R/W	0

#### DECCTL (VOICE DECODER CONTROL REGISTER, 0x274D)

Bit Field	Name	Descriptions	R/W	Reset Value
7	LPB	Loopback Test. When this field is set to '1', Loopback test mode is selected. In this case, the output of voice encoder is connected to the input of voice decoder.	R/W	0
6		Reserved	R/W	0
5	B16	The bit width of data which is output from voice decoder is 16-bit, set this field to '1'. When this field is set to '0', the bit width of data which is output from voice decoder is 8-bit.	R/W	0
4	MUT	Mute Enable. When this field is set to '1', Mute function is enabled. DECMUT1 and DECMUT0 values are transferred from voice decoder.	R/W	0
3:2	SEL	Decoder Select. Select voice decoder. 0: No Decoding 1: $\mu$ -law 2: a-law 3: ADPCM	R/W	0

1	INI	When this field is set to '1', the pointer in voice decoder is initialized. This field cannot be read.	W	0
0	ENA	Decoder Enable. When this field is set to '1', voice decoder enabled.	R/W	0

### 8.10.3. VOICE FIFO

Data received via I2S interface is compressed by voice encoder; compressed data is stored in Voice TXFIFO (0x2800~0x28FF). The size of Voice TXFIFO is 256 byte.

Data in MAC RXFIFO is processed by DMA operation, and stored in Voice RX FIFO (0x2900~0x29FF). Data in Voice RXFIFO is decompressed by the voice decoder and transmitted to an external component via I2S. The size of Voice RXFIFO is 256 byte.

#### 8.10.3.1. VOICE TX FIFO CONTROL

##### VTFDAT (VOICE TX FIFO DATA REGISTER, 0x2750)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	VTFDAT	When writing data to this register, data is stored in Voice TX FIFO in order. When reading this register, data stored in Voice TX FIFO can be read.	R/W	0x00

##### VTFMUT (VOICE TX FIFO MUTE DATA REGISTER, 0x2751)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	VTFMUT	When MUT field in VTFCTL register is set to '1', data in this register is transferred instead of data in Voice TX FIFO. When INI field in VTFCTL register is set to '1', data in Voice TX FIFO is initialized by data in VTFMUT.	R/W	0x00

##### VTFCTL (VOICE TX FIFO CONTROL REGISTER, 0x2752)

Bit Field	Name	Descriptions	R/W	Reset Value
7:4		Reserved		0
3	VTDNA	Voice TX DMA Enable. When this field is set to '1', Voice TX DMA is enabled. This field value is cleared automatically.	W/O	0
2	MUT	When this field is set to '1', data in VTFMUT register is transferred instead of data in Voice TX FIFO. This field can be read.	R/W	0
1	CLR	When this field is set to '1', Write pointer and Read pointer of Voice TX FIFO are	W/O	0

		initialized. The status value of underflow and overflow is initialized.		
0	INI	When this field is set to '1', all data in Voice TXFIFO is replaced by the value in VTFMUT register.	W/O	0

**VTFRP (VOICE TX FIFO READ POINTER REGISTER, 0x2753)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	VTFRP	This register indicates the address of Voice TXFIFO to be read next. Since the size of FIFO is 256 byte, LSB is used to test wrap-around.	R/W	0x00

**VTFWP (VOICE TX FIFO WRITE POINTER REGISTER, 0x2754)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	VTFWP	This register indicates the address of Voice TXFIFO to be written next. Since the size of FIFO is 256 byte, LSB is used to test wrap-around.	R/W	0x00

**VTFSTS (VOICE TX FIFO STATUS REGISTER, 0x275A)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:5		Reserved		0
4	ZERO	When INI field in VTFCTL register is set to '1', data in Voice TX FIFO is initialized by data in VTFMUT register. During this initialization is processed, this field is set to '1'. After initialization is finished, this field is set to '0'.	R/O	0
3	PSH	This field is set to '1' while pushing data into Voice TX FIFO.	R/O	0
2	POP	This field is set to '1' while popping data on Voice TX FIFO.	R/O	0
1:0		Reserved		0

**VTDSIZE (VOICE TX DMA SIZE REGISTER(VOICE TX FIFO->MAC TX FIFO), 0x275B)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	VTDSIZE	Set the data size for DMA operation.	R/W	0x00

**8.10.3.2. VOICE RX FIFO CONTROL****VRFDAT (VOICE RX FIFO DATA REGISTER, 0x2760)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	VRFDAT	When writing data to this register, data is	R/W	0x00

		stored in Voice RX FIFO in order. When reading this register, data stored in Voice RX FIFO can be read.		
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**VRFMUT (VOICE RX FIFO MUTE DATA REGISTER, 0x2761)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	VRFMUT	When MUT field in VRFCTL register is set to '1', data in this register is transferred instead of data in Voice RX FIFO. When INI field in VRFCTL register is set to '1', data in Voice RX FIFO is initialized by data in VTFMUT.	R/W	0x00

**VRFCTL (VOICE RX FIFO CONTROL REGISTER, 0x2762)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:4		Reserved		0
3	VRDENA	Voice RX DMA Enable. When this field is set to '1', Voice RX DMA is enabled. This field value is cleared automatically	W/O	0
2	MUT	When this field is set to '1', data in the VRFMUT register is transferred instead of data in the Voice RX FIFO. This field can be read.	R/W	0
1	CLR	When this field is set to '1', Write pointer and Read pointer of Voice RX FIFO are initialized. The status value of underflow and overflow is initialized.	W/O	0
0	INI	When this field is set to '1', all data in Voice RXFIFO is replaced by the value in VRFMUT register.	W/O	0

**VRFRP (VOICE RX FIFO READ POINTER REGISTER, 0x2763)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	VRFRP	This register indicates the address of Voice RXFIFO to be read next. Since the size of FIFO is 256 byte, the LSB is used to test wrap-around.	R/W	0x00

**VRFWP (VOICE RX FIFO WRITE POINTER REGISTER, 0x2764)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	VRFWP	This register indicates the address of Voice RXFIFO to be written next. Since the size of FIFO is 256 byte, the LSB is used to test wrap-around	R/W	0x00

**VRFSTS (VOICE RX FIFO STATUS REGISTER, 0x276A)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:5		Reserved		0
4	ZERO	When INI field in VRFCTL register is set to '1', data in the Voice TX FIFO is initialized by the data in the VRFMUT register. During the processing of this initialization, this field is set to '1', and set to '0' when initialization is finished.	R/O	0
3	PSH	This field is set to '1' while pushing data into the Voice RX FIFO.	R/O	0
2	POP	This field is set to '1' while popping data on the Voice RX FIFO.	R/O	0
1:0		Reserved		0

**VRDSIZE (VOICE RX DMA SIZE REGISTER (MAC RX FIFO->VOICE RX FIFO), 0x276B)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	VRDSIZE	Sets the data size for DMA.	R/W	0x00

**8.10.3.3. VOICE INTERFACE CONTROL****VTFINTENA (VOICE TX FIFO INTERRUPT ENABLE REGISTER, 0x2770)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	EMPTY	Voice TX FIFO Empty Interrupt Enable	R/W	0
6	FULL	Voice TX FIFO Full Interrupt Enable	R/W	0
5:0		Should be set as '0'.		0

**VRFINTENA (VOICE RX FIFO INTERRUPT ENABLE REGISTER, 0x2771)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	EMPTY	Voice RX FIFO Empty Interrupt Enable	R/W	0
6	FULL	Voice RX FIFO Full Interrupt Enable	R/W	0
5:0		Should be set as '0'.		0

**VMINTENA (VOICE DMA CONTROLLER INTERRUPT ENABLE REGISTER, 0x2772)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:5		Should be set as '0'.		0
4	VTDDONE	Voice TX DMA Done Interrupt Enable	R/W	0
3:1		Should be set as '0'.		0
0	VRDDONE	Voice RX DMA Done Interrupt Enable	R/W	0

**VTFINTSRC (VOICE TX FIFO INTERRUPT SOURCE REGISTER, 0x2773)**

Bit	Name	Descriptions	R/W	Reset
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Field				Value
7	EMPTY	Voice TX FIFO Empty Interrupt Source. When EMPTY field in VTFINTENA register is set to '1' and EMPTY field in VTFINTVAL register is set to '1', this field is set to '1'. Cleared by software.	R/W	0
6	FULL	Voice TX FIFO Full Interrupt Source	R/W	0
5:0		Reserved		0

**VRFINTSRC (VOICE RX FIFO INTERRUPT SOURCE REGISTER, 0x2774)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	EMPTY	Voice RX FIFO Empty Interrupt Source	R/W	0
6	FULL	Voice RX FIFO Full Interrupt Source	R/W	0
5:0		Reserved		0

**VDMINTSRC (VOICE DMA CONTROLLER INTERRUPT SOURCE REGISTER, 0x2775)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:5		Should be set as '0'.		0
4	VTDDONE	Voice TX DMA Done Interrupt Source	R/W	0
3:1		Should be set as '0'.		0
0	VRDDONE	Voice RX DMA Done Interrupt Source	R/W	0

**SRCCTL (VOICE SOURCE CONTROL REGISTER, 0x277A)**

Bit Field	Name	Descriptions	R/W	Reset Value
7		Should be set as '0'.		0
6:5	MUX	Selects the specific interface to communicate between voice encoder/decoder and external data. 0: I2S 1: SPI 2: UART0 3: UART1	R/W	0
4:0		Should be set as '0'.		0

**VSPCTL (VOICE SOURCE PATH CONTROL REGISTER, 0x277E)**

Bit Field	Name	Descriptions	R/W	Reset Value
7		Reserved		0
6	DECMUT	This register is used to send mute data from voice decoder to the external interface. When this field is set to '1', VSPMUT1 and VSPMUT0 value are transferred to the external interface.	R/W	0
5	DECINI	When using 8-bit external interface, 16-bit data transferred from voice decoder	R/W	0



		needs to be changed to 8-bit. When this field is set to '1', corresponding control circuit is initialized.		
4	DECB16	When using 8-bit external interface such as UART and so on, 16-bit data transferred from voice decoder needs to be changed to 8-bit. When this field is set to '1', high 8-bit data of 16-bit data is transferred first and then low 8-bit data is transferred.	R/W	0
3		Reserved		0
2	ENCMUT	This register is used to send mute data from external interface to voice encoder. When this field is set to '1', VSPMUT1 and VSPMUT0 values are transferred to voice encoder.	R/W	0
1	ENCINI	When using 8-bit external interface, 16-bit data transferred to voice encoder needs to be changed to 16-bit. When this field is set to '1', corresponding control circuit is initialized.	R/W	0
0	ENCB16	When using 8-bit external interface, 8-bit input data needs to be changed to 16-bit, which is compatible with the voice encoder. When this field is set to '1', it is changed to 16-bit.(8-bit received first: high bit 8-bit received later: low bit)	R/W	0

#### VSPMUX (VOICE SOURCE PATH MUX CONTROL REGISTER, 0x277F)

Bit Field	Name	Descriptions	R/W	Reset Value
7:3		Reserved.	R/W	0
2:0	VSPMUX	0: The 256 bytes voice RX/TX FIFO mapped to voice RX/TX FIFO. 1: Voice RX/TX FIFO mapped to UART0 RX/TX FIFO. 2: Voice RX/TX FIFO mapped to UART1 RX/TX FIFO. 3: Voice RX/TX FIFO mapped to SPI RX/TX FIFO. 7: Voice RX/TX FIFO memory mapped to data memory area (0x1700-0x19FF). The data memory area can be extended by the register value.	R/W	0

## 8.11. Random Number Generator(RNG)

The random number generator (RNG) generates 32-bit random number with seed. Whenever ENA bit in RNGC register is set to '1', the generated number is stored in RNGD3 ~ RNGD0 register.

### RNGD3 (RNG DATA3 REGISTER, 0x2550)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	RNGD3	This register stores MSB (RNG[31:24]) of 32-bit random number.	R/O	0xB7

### RNGD2 (RNG DATA2 REGISTER, 0x2551)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	RNGD2	This register stores 2 <sup>nd</sup> MSB (RNG[23:16]) of 32-bit random number.	R/O	0x91

### RNGD1 (RNG DATA1 REGISTER, 0x2552)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	RNGD1	This register stores 3 <sup>rd</sup> MSB (RNG[15:8]) of 32-bit random number.	R/O	0x69

### RNGD0 (RNG DATA0 REGISTER, 0x2553)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	RNGD0	This register stores LSB (RNG[7:0]) of 32-bit random number.	R/O	0xC9

### SEED3 (RNG SEED3 REGISTER, 0x2554)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	SEED3	This register stores MSB (SEED[31:24]) of required seed to generate random number.	W/O	-

### SEED2 (RNG SEED2 REGISTER, 0x2555)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	SEED2	This register stores 2 <sup>nd</sup> MSB (SEED[23:16]) of required seed to generate random number.	W/O	0x00

### SEED1 (RNG SEED1 REGISTER, 0x2556)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	SEED1	This register stores 3 <sup>rd</sup> MSB (SEED[15:8]) of required seed to generate random number.	W/O	0x00

#### SEED0 (RNG SEED0 REGISTER, 0x2557)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	SEED0	This register stores LSB (SEED[7:0]) of required seed to generate random number.	W/O	0x00

#### RNGC (RNG DATA3 REGISTER, 0x2558)

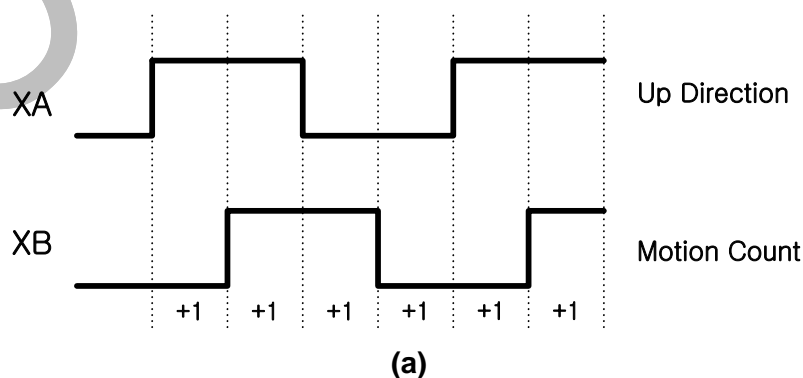
Bit Field	Name	Descriptions	R/W	Reset Value
7:1		Reserved		0
0	ENA	RNG Enable. When this field is set to '1', RNG acts. This field value is changed to '0' automatically.	R/W	0

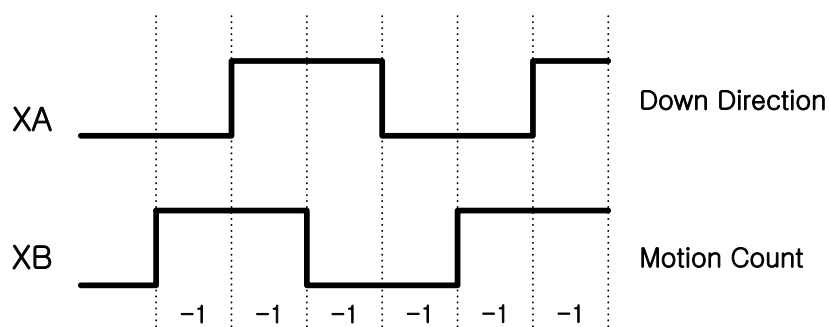
## 8.12. Quadrature Signal Decoder

The Quadrature Signal Decoder block notifies the MCU of the counter value based on the direction and movement of a pointing device, such as a mouse, after receiving Quadrature signal from the pointing device.

Quadrature signal is changed with 90° phase difference (1/4 period) between two signals as shown in [Figure 17]. In addition, counter value means 1/4 of one period. Since this block can receive three Quadrature signals, it can support not only the two-dimensional movement such as mouse but also the pointing device which is in three dimensions.

The (a) of [Figure 17] shows that the XA signal is changing before the XB signal. In this case, the pointing device is moving in the up direction. The (b) of [Figure 17] shows that XB signal is changing before XA signal. In this case, the pointing device is moving in the down direction. The rules for YA, YB, ZA and ZB are the same as described above for XA and XB.





(b)

Figure 17. Quadrature signal timing between XA and XB

**UDX (UpDown X Register, 0x2560)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:1		Reserved		0
0	UPDN_X	This field notifies the MCU of movement in the X-axis direction. 1: Up 0: Down	R/O	0

**CNTX (Count X Register, 0x2561)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	CNTX	This field notifies the MCU of the count value for movement in the X-axis.	R/O	0x00

**UDY (UpDown Y Register, 0x2562)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:1		Reserved		
0	UPDN_Y	This field notifies the MCU of movement in the Y-axis. 1: Up 0: Down	R/O	0

**CNTY (Count Y Register, 0x2563)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	CNTY	This field notifies the MCU of the count value for movement in the Y-axis.	R/O	0x00

**UDZ (UpDown Z Register, 0x2564)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:1		Reserved		0x00
0	UPDN_Z	This field notifies the MCU of movement in the Z-axis.	R/O	0

		1: Up 0: Down		
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**CNTZ (Count Z Register, 0x2565)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	CNTZ	This field notifies the MCU of the count value for movement in the Z-axis.	R/O	0x00

**QCTL (Quad Control Register, 0x2566)**

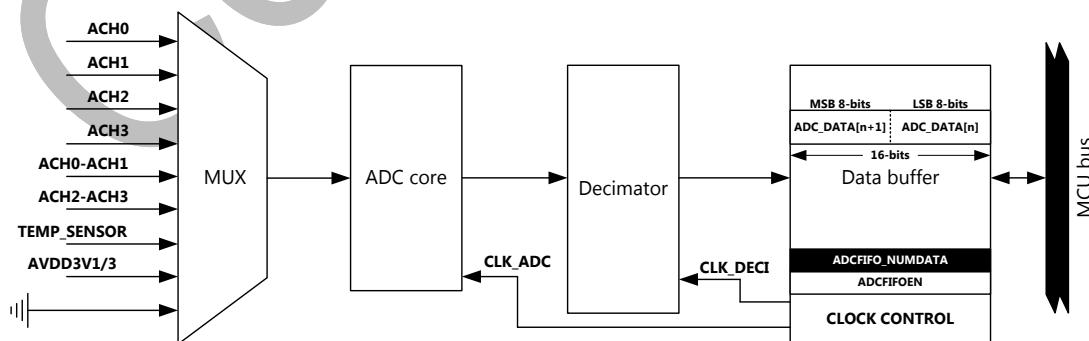
Bit Field	Name	Descriptions	R/W	Reset Value
7:3		Reserved		x
2	ENA	Quad Enable. When this field is set to '1', Quadrature Signal Decoder is enabled.	R/W	
1	INI	Quad Initialize. When this field is set to '1', internal register values of Quadrature Signal Decoder are initialized.	R/W	
0		Reserved	R/W	0

**8.13. ADC**

MG2470 supports the 4-channel ADC with 12bit resolution. The ADC includes an analog multiplexer with up to four individually configurable channels, sigma-delta modulator, decimator, and ADC FIFO. The converted values can be obtained by reading ADCVAL (0x22D7) twice.

The main features of the ADC are as follows;

- Selectable decimation rates and sampling clock
- Four individual input channels, single-ended or differential-ended
- Temperature sensor input
- Battery measurement capability



**PHY\_CLK\_EN1 (ADC CLOCK ENABLE REGISTER, 0x2781)**

Bit Field	Name	Descriptions	R/W	Reset Value
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3	CLK_ADC_EN	ADC sampling clock on/off. The default value is 0(disabled). The clock rate selection among 1, 2, and 4MHz is done through register ADC_CLK_SEL(0x2786)	R/W	0
2	CLK_DECI_EN	The digital decimator clock on/off. The default value is 0(disabled). The clock rate of CLK_DECI is always 16MHz.	R/W	0

**PHY\_SW\_RSTB (DECIMATOR RESET REGISTER, 0x2784)**

Bit Field	Name	Descriptions	R/W	Reset Value
6	RESETB_DECI	Active low reset for digital decimator. This register is not automatically cleared, so the register should be restored manually.	R/W	1

**ADC\_CLK\_SEL (ADC SAMPLING RATE CONFIGURATION REGISTER, 0x2786)**

Bit Field	Name	Descriptions	R/W	Reset Value
1:0	ADC_CLK_SEL	The ADC sampling clock rate can be selected among 1, 2, and 4MHz (0x0=1MHz, 0x1=2MHz, 0x2=4MHz, 0x3=Not used) .	R/W	0x2

**ADCNF1 (ADC CONFIGURATION1 REGISTER, 0x22D4)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	ADCEN	ADC core is activated when it is set to 1.	R/W	0
6:5	ADCREF	The selection of the voltage reference of ADC core. 0x0: Bandgap reference (1.25V) is used. 0x1: Reserved 0x2: AVDD3V1/3 is used. 0x3: internal voltage regulator output is used.	R/W	0x0
4	-	Reserved	R/W	0
3:0	ADCHCNF	ADC channel selection. 0x0: ACH0 0x1: ACH1 0x2: ACH2 0x3: ACH3 0x4: ACH0 - ACH1 0x5: ACH2 - ACH3 0x6: Temperature sensor 0x7: Battery monitor(AVDD3V1) 0x8: GND The configurations of 0x7 and 0x8 can be used the ADC calibration.	R/W	0x0

**ADCNF2 (ADC CONFIGURATION2 REGISTER, 0x22D5)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:4	ADCFIFOSIZE	The size of ADC FIFO. The number of available data in FIFO is ADCFIFOSIZE	R/W	0xC

		- 1.		
3:2	ADCOSRSEL	Oversampling ratio of ADC 0x0: Not used 0x1: 64x 0x2: 128x 0x3: 256x	R/W	0x3
1	ADCFIFOEN	Data buffer mode selection. 0: normal delayed buffer, recent samples(ADCFIFOTHRINTR-1) samples are available in the ADC buffer(interrupt is not generated). 1: FIFO mode, when the buffer is full, the data is not stacked in the buffer(before the buffer is full, the data in the buffer should be read out).	R/W	1

**ADCSTS (ADC STATUS MONITORING REGISTER, 0x22D6)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	-	Reserved	R	0
6:3	ADCFIFO_NUM DATA	This field determines number of available data in buffer. Number of available data is ADCFIFO_NUMDATA - 1. The data ready check is possible by !(ADCSTS&0x70)	R	0x0
2:0	-	Reserved	R	0x0

**ADCVAL (ADC CONVERSION RESULTS READ-OUT REGISTER, 0x22D7)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	ADC_DATA	The ADC values in 16bit can be obtained by reading this register twice. The LSB 8bit and MSB 8bit can be read sequentially. Note: Effective resolution(12bit) is acquired by $(MSB*256+LSB+8)/16$	R	0x00

## 8.14. Power Management

MG2470 has four operation modes to allow low power consumption. PM0 is the normal operating mode. The other 3 modes, PM1/PM2/PM3, are called power down modes.

### ■ PM0

PM0 is the normal operating mode where the RF transceiver, MCU, and peripherals are active. In PM0, all voltage regulators are on.

### ■ PM1

PM1 is the power down mode where the 32MHz crystal oscillator and the 16MHz RC oscillator are powered down. The voltage regulator for digital core, the 32kHz oscillator, and the sleep timer are on. MG2470 wakes up from PM1 to PM0 by turning on the 16MHz RC oscillator and the 32MHz crystal oscillator when interrupts are occurred. MG2470 will run on the 16MHz RC oscillator and automatically switch clock source to the 32MHz crystal oscillator after the 32MHz crystal oscillator has settled.



### ■ PM2

PM2 is the power down mode where the 32MHz crystal oscillator, the 16MHz RC oscillator, and the voltage regulator for digital core are powered down. In PM2, the 32kHz oscillator and the sleep timer are on. MG2470 wakes up from PM2 to PM0 by turning on the voltage regulator, the 16MHz RC oscillator, and the 32MHz crystal oscillator when interrupts are occurred. Each I/O pins retain the output value set GPIOPS0(0x22E7), GPIOPS1(0x22E8), GPIOPS3(0x22E9), GPIOPE0(0x22EA), GPIOPE1(0x22EB), and GPIOPE3(0x22EC) before entering PM2. PM2 is used when it is relatively long until the expected time for wakeup event.

### ■ PM3

PM3 is the power down mode where all clock oscillators, the voltage regulator, and sleep timer are powered down. MG2470 wakes up from PM3 to PM0 by turning on the voltage regulator, the 16MHz RC oscillator, and the 32MHz crystal oscillator when interrupts are occurred. Each I/O pins retain the output value set GPIOPS0(0x22E7), GPIOPS1(0x22E8), GPIOPS3(0x22E9), GPIOPE0(0x22EA), GPIOPE1(0x22EB), and GPIOPE3(0x22EC) before entering PM3. PM3 is used to achieve ultra low power consumption.

### ■ Power Management Control

Power down modes (PM1/PM2/PM3) can be set by PDMODE[1:0] in PDCON(0x22E0) register. After setting PDMODE, each power mode can be started by making PCON bit[1] to 1.

MG2470 will wake up from power down modes to PM0 by interrupts, which are the selected I/O pins, the sleep timer, and the external reset.

All I/O pins can be set as wake up source by set GPIOMSK0(0x22F0), GPIOMSK1(0x22F1), and GPIOMSK3(0x22F2) and polarity of the I/O pins can be set by GPIOPOL0(0x22ED), GPIOPOL1(0x22EE), and GPIOPOL3(0x22EF).

Minimum operation time in PM0 must be over 30usec to re-enter into PM1/PM2/PM3.

## 8.15. Sleep Timer

Sleep timer is used to exit from the power down modes(PM1/PM2/PM3) The desired clock is generated from the 32kHz RC oscillator or inputs from an external 32.768kHz clock at P1[4] by setting SELRTCLK in PDCON(0x22E0). The sleep timer is activated as setting STEN bit in PDCON(0x22E0) to 1 and the interrupt interval can be programmed by setting RTINT1(0x22E3), RTINT2(0x22E4), RTINT3(0x22E5), and EXPRTVAL bits in PDMON(0x22E6).

Sleep timer can be also used to RTC interrupt source in the normal operation mode(PM0).

Sleep timer interval(sec) is calculated by  $65536 * EXPRTVAL[1:0] + RTVALSEC[15:0] + 3.90625m * RTVALSUB[7:0]$ .

## 8.16. 32kHz RC Oscillator

MG2470 has a low-power 32kHz RC oscillator for Sleep timer and watchdog timer. 32kHz RC oscillator is activated when RCOSCEN in PDCON(0x22E0) is set to 1. When the 32MHz crystal oscillator is selected and it is stable, i.e. OSCOK in PDMON(0x22E6) is 1, Frequency calibration of the 32kHz RC oscillator is continuously performed by setting RCCEN in RCOSCON(0x22E1). This calibration is performed in PM0 and retains the last calibration value in power down mode.



## 8.17. 16MHz RC Oscillator

MG2470 can run on the 16MHz RC oscillator until 32MHz crystal oscillator is stable for fast turn-on time. The 16MHz RC oscillator is activated when HSRCOSCEN in PDCON(0x22E0) is set to 1. When the 32MHz crystal oscillator is selected and it is stable, i.e. OSCOK in PDMON(0x22E6) is 1, Frequency calibration of the 16MHz RC oscillator is continuously performed by setting HSRCCEN in RCOSCON(0x22E1). This calibration is performed in PM0 and retains the last calibration value in power down mode. The 16MHz RC oscillator consumes less power than the 32MHz crystal oscillator, but it cannot be used for RF transceiver operation.

The 16MHz RC oscillator is automatically turned off in the power down modes. When exiting from the power down mode, HSRCOSC\_STS bit (CLKCON2, 0x8F) should be cleared in order to return to the normal mode and HSRCOSC\_SEL bit (CLKCON1, 0x8E) should be set to 0 for switching the clock source to the 32MHz crystal oscillator.

## 8.18. 32MHz Crystal Oscillator

The crystal oscillator generates the reference clock for MG2470. An external 32MHz with two loading capacitors (C11 and C12) is used for the 32MHz crystal oscillator. The load capacitance seen by the 32MHz crystal is given by

$$C_L = \frac{1}{\frac{1}{C_{11}} + \frac{1}{C_{12}}} + C_{\text{parasitic}}$$

where  $C_{\text{parasitic}}$  represents all parasitic capacitances such as PCB stray capacitance and the package pin capacitance.

## 8.19. Always-On Registers

All registers bits retain their previous values when entering PM2 or PM3.

### PDCON (POWER DOWN CONTROL REGISTER, 0x22E0)

Bit Field	Name	Descriptions	R/W	Reset Value
7	BODEN	It enables the Brown out detector(BOD), when DVDD falls under operation voltage. 1: Enables the Brown out detector. 0: Disables the Brown out detector.	R/W	1
6	AVREGEN	It controls voltage regulators in Analog part. It must be set to 0 before entering PM0/PM1/PM2 1: Enables voltage regulators in Analog part. 0: Disables voltage regulators in Analog part.	R/W	1
5	STEN	Register for controlling the sleep timer. When STEN is set to 1, the sleep timer operates by 32kHz RC oscillator or external 32.768kHz clock from P1[4]. 1: Enables the sleep timer.	R/W	0

		0: Disables the sleep timer.		
4	HSRCOSCEN	It decides oscillation of the 16MHz RC oscillator. The 16MHz RC oscillator is used for fast turn on from PM1/2/3 or initial power up sequence. 1: Enables the 16MHz RC oscillator. 0: Disables the 16MHz RC oscillator.	R/W	1
3	RCOSCEN	It decides oscillation of the 32kHz RC oscillator. Output clock of the 32kHz RC oscillator is used for sleep timer and the watchdog timer. 1: Enables the 32kHz RC oscillator. 0: Disables the 32kHz RC oscillator.	R/W	1
2	SELRTCLK	It selects sleep timer clock source. When this field is set to 0, output clock of the 32kHz RC oscillator is used as a clock source. Optionally, the external 32.768kHz clock from P1[4] is used as a clock source of the sleep timer by setting to 1	R/W	0
1:0	PDMODE	Register for power down mode of MG2470 00: Normal operation mode 01: PM1 10: PM2 11: PM3	R/W	00

**RCOSC (RC OSCILLATOR CALIBRATION REGISTER, 0x22E1)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	-	Reserved	R	1
6	HSRCCEN	It enables or disables calibration block in the 16MHz RC oscillator. 1: Enables 16MHz RC Calibration. 0: Disables 16MHz RC Calibration.	R/W	0
5	HSRCCRSTB		R/W	0
4	-	Reserved	R	1
3	RCCEN	It enables or disables calibration block in the 32kHz RC oscillator. 1: Enables 32kHz RC Calibration. 0: Disables 32kHz RC Calibration.	R/W	1
2	RCCRSTB		R/W	0
1	-	Reserved	R/W	0
0	-	Reserved.	R/W	0

**RTINT1 (SLEEP TIMER INTERVAL CONTROL REGISTER, 0x22E3)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	RTVALSEC[15:8]	This field determines the Sleep timer interval with RTINT2, RTINT3, and RTINT4.	R/W	0x00

**RTINT2 (SLEEP TIMER INTERVAL CONTROL REGISTER, 0x22E4)**

Bit	Name	Descriptions	R/W	Reset
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Field	Name	Descriptions	R/W	Value
7:0	RTVALUESEC[7:0]	This field determines the Sleep timer interval with RTINT1, RTINT3, and RTINT4.	R/W	0x01

**RTINT3 (SLEEP TIMER INTERVAL CONTROL REGISTER, 0x22E5)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	RTVALSUB[7:0]	This field determines the Sleep timer interval with RTINT1, RTINT2, and RTINT4.	R/W	0x00

**RTINT4 (RC OSCILLATOR CALIBRATION REGISTER, 0x22E6)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	-	Reserved	R	0
6	OSCOK	32MHz crystal oscillator status: 0: 32MHz crystal oscillator is not yet stable. 1: 32MHz crystal oscillator is stable.	R	0
5	-	Reserved	R	000
4:3	EXPRTVL	This field determines the Sleep timer interval with RTINT1, RTINT2, and RTINT3.	R	00
2	ACHMEN	It enables or disables ADC input MUX. 1: Enables ADC input MUX. 0: Disables ADC input MUX. (ACH0-ACH3 pins are floated)	R/W	1
1:0	-	Reserved	R/W	11

**GPIOPS0 (PORT 0, PULL-UP/PULL-DOWN SELECT REGISTER, 0x22E7)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	GPIO0_PS	This field selects the configuration of Port 0 as pull-up/pull-down inputs 0: pull-down 1: pull-up	R/W	0xFF

**GPIOPS1 (PORT 1, PULL-UP/PULL-DOWN SELECT REGISTER, 0x22E8)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	GPIO1_PS	This field selects the configuration of Port 1 as pull-up/pull-down inputs 0: pull-down 1: pull-up	R/W	0xFF

**GPIOPS3 (PORT 3, PULL-UP/PULL-DOWN SELECT REGISTER, 0x22E9)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	GPIO3_PS	This field selects the configuration of Port 3 as pull-up/pull-down inputs 0: pull-down 1: pull-up	R/W	0xFF

**GPIOE0 (PORT 0, INPUT MODE, 0x22EA)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	GPIO0_PE	This field selects input mode of the Port 0. 0: tri-state 1: pull-up/pull-down ( see GPIOPS0(0x22E7))	R/W	0xFF

**GPIOE1 (PORT 1, INPUT MODE, 0x22EB)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	GPIO1_PE	This field selects input mode of the Port 1. 0: tri-state 1:pull-up/pull-down(see PIOPS0(0x22E8))	R/W	0xFF

**GPIOE3 (PORT 3, INPUT MODE, 0x22EC)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	GPIO3_PE	This field selects input mode of the Port 3. 0: tri-state 1:pull-up/pull-down(see PIOPS0(0x22E9))	R/W	0xFF

**GPIOPOL0 (PORT 0, INTERRUPT POLARITY, 0x22ED)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	GPIO0_POLH	This field changes the polarity of the Port 0. Port 0 is used the wake up source in the PM1/2/3 0: recognizes low level as interrupt signal. 1: recognizes high level as interrupt signal.	R/W	0x00

**GPIOPOL1 (PORT 1, INTERRUPT POLARITY, 0x22EE)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	GPIO1_POLH	This field changes the polarity of the Port 1. Port 1 is used the wake up source in the PM1/2/3 0: recognizes low level as interrupt signal. 1: recognizes high level as interrupt signal.	R/W	0x00

**GPIOPOL3 (PORT 3, INTERRUPT POLARITY, 0x22EF)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	GPIO3_POLH	This field changes the polarity of the Port 3. Port 3 is used the wake up source in the PM1/2/3 0: recognizes low level as interrupt signal. 1: recognizes high level as interrupt signal.	R/W	0x00

**GPIOMSK0 (PORT 0, INTERRUPT MASK, 0x22F0)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	GPIO0_MSK	Port 0 interrupt mask. Port 0 is used the wake up source when this field is set to 1 in PM1/2/3. 0: No interrupt will be acknowledged. 1: Port 0 is individually enabled and Port 0 is used the wake up source.	R/W	0x00

**GPIOMSK1 (PORT 1, INTERRUPT MASK, 0x22F1)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	GPIO1_MSK	Port 1 interrupt mask. Port 1 is used the wake up source when this field is set to 1 in PM1/2/3. 0: No interrupt will be acknowledged. 1: Port 1 is individually enabled and Port 1 is used the wake up source.	R/W	0x00

**GPIOMSK3 (PORT 3, INTERRUPT MASK, 0x22F2)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:4,	GPIO3_MSK	Port 3 interrupt mask. Port 3 is used the wake up source when this field is set to 1 in PM1/2/3. 0: No interrupt will be acknowledged. 1: Port 3 is individually enabled and Port 3 is used the wake up source.	R/W	0x00
3:2		Reserved		
1:0	GPIO3_MSK	Port 3 interrupt mask. Port 3 is used the wake up source when this field is set to 1 in PM1/2/3. 0: No interrupt will be acknowledged. 1: Port 3 is individually enabled and Port 3 is used the wake up source.	R/W	0x00

## 9. TRANSCEIVER

### 9.1. MAC

The MAC block transmits the data received from high layer to baseband modem, or encrypts it and then transmits to baseband modem. In addition, it indicates the status of PHY and transmits the data received from baseband modem to high layer, or transmits the decrypted data to high layer.

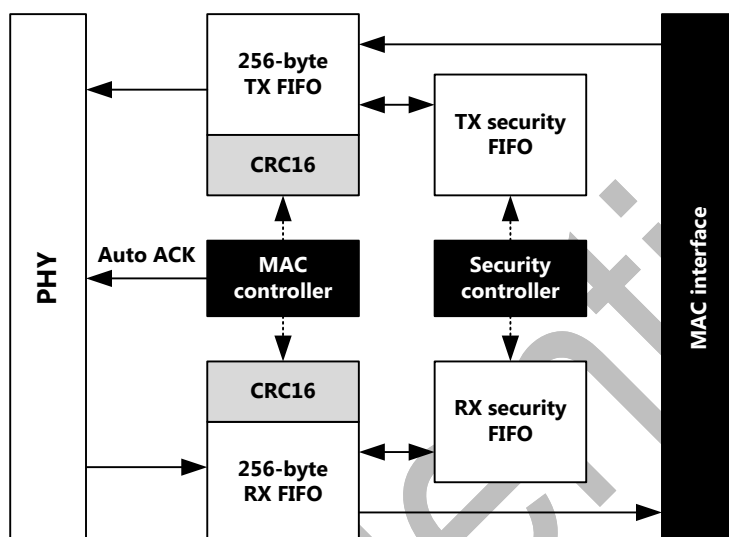


Figure 18. MAC block diagram

[Figure 18] shows the MAC block structure. The RX and TX FIFOs are separately implemented. The size of each FIFO is 256 bytes in order to process one IEEE802.15.4 packet along with buffering one packet. The MAC FIFO and security FIFO share the address space and are distinguished by setting the register of SECMAP (0x219F). The following table shows the address space of each FIFO.

#### MTXFIFO or STXFIFO (MAC TX FIFO or SECURITY TX FIFO, 0x2300~0x23FF)

Name	Descriptions	R/W	Reset Value
MTXFIFO or STXFIFO	Random access space for MAC TX FIFO (MTXFIFO; SECMAP = 0) or security TX FIFO (STXFIFO; SECMAP = 1)	R/W	0x00

#### MRXFIFO or SRXFIFO (MAC RX FIFO or SECURITY RX FIFO, 0x2400~0x24FF)

Name	Descriptions	R/W	Reset Value
MRXFIFO or SRXFIFO	Random access space for MAC RX FIFO (MRXFIFO; SECMAP = 0) or RX security FIFO (SRXFIFO; SECMAP = 1)	R/W	0x00

The general MAC/security control registers except for FIFO control registers are prepared as following.

**KEY0 (ENCRYPTION KEY 0 REGISTER, 0x2100~0x210F)**

Bit Field	Name	Descriptions	R/W	Reset Value
127:0	KEY0	16-byte key (KEY0) for AES-128 0x210F: Most significant byte	R/W	0

**RXNONCE (RX NONCE FOR AUTHENTICATION REGISTER, 0x2110~0x211C)**

Bit Field	Name	Descriptions	R/W	Reset Value
103:0	RXNONCE	Used for decryption: 8-byte source address + 4-byte frame counter + 1-byte key sequence counter 0x211C: Most significant byte of source address 0x2114: Most significant byte of frame counter 0x2110: Key sequence counter	R/W	0

**KEY1 (ENCRYPTION KEY 1 REGISTER, 0x2130~0x213F)**

Bit Field	Name	Descriptions	R/W	Reset Value
127:0	KEY1	16-byte key (KEY1) for AES-128 0x213F: Most significant byte	R/W	0

**TXNONCE (TX NONCE FOR AUTHENTICATION REGISTER, 0x2140~0x214C)**

Bit Field	Name	Descriptions	R/W	Reset Value
103:0	TXNONCE	Used for encryption: 8-byte source address + 4-byte frame counter + 1-byte key sequence counter 0x214C: Most significant byte of source address 0x2144: Most significant byte of frame counter 0x2140: Key sequence counter	R/W	0

**EXTADDR (EXTENDED ADDRESS REGISTER, 0x2150~0x2157)**

Bit Field	Name	Descriptions	R/W	Reset Value
63:0	EXTADDR	64-bit IEEE address 0x2157: Most significant byte	R/W	0

**PANID (PAN IDENTIFIER REGISTER, 0x2158~0x2159)**

Bit Field	Name	Descriptions	R/W	Reset Value
15:0	PANID	16-bit PAN ID 0x2159: Most significant byte	R/W	0

**SHORTADDR (SHORT ADDRESS REGISTER, 0x215A~0x215B)**

Bit Field	Name	Descriptions	R/W	Reset Value
15:0	SHORTADDR	16-bit short (network) address 0x215B: Most significant byte	R/W	0

**MACSTS (MAC/SECURITY STATUS REGISTER, 0x2180)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	ENCDEC	When this field is set to '1', there is data in the encryption or decryption.	R	0
6	TX_BUSY	When this field is set to '1', data in the TX FIFO is transmitted to a modem.	R	0
5	RX_BUSY	When this field is set to '1', data is transmitted from a modem to the RX FIFO.	R	0
4		Reserved		
3	DECODE_OK	This field checks the validity of data according to the type of data received or the address mode. If there is no problem, this field is set to '1'	R	0
2	ENC_DONE	When encryption operation is finished, this field is set to '1'.	R/W	0
1	DEC_DONE	When decryption operation is finished, this field is set to '1'.	R/W	0
0	CRC_OK	If there is no problem for checking CRC of received packet, this field is set to '1'.	R/W	0

**MACRST (MAC/SECURITY RESET REGISTER, 0x2190)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	RST_FIFO	When this field is set to '1', the MAC FIFO is initialized.	R/W	0
6	RST_TSM	When this field is set to '1', the MAC TX state machine is initialized.	R/W	0
5	RST_RSM	When this field is set to '1', the MAC RX state machine is initialized.	R/W	0
4	RST_AES	When this field is set to '1', the AES engine is initialized.	R/W	0
3:0		Reserved		0x0

**MACCTRL (MAC CONTROL REGISTER, 0x2191)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:5		Reserved		0x0
4	PREVENT_ACK	When this field is set to '1', the RX interrupt doesn't occur when the DSN field of received ACK packet is different from the value	R/W	0



		in MACDSN register during packet reception.		
3	PAN_COORDINATOR	When this field is set to '1', function for PAN coordinator is enabled.	R/W	0
2	ADR_DECODE	When this field is set to '1', the RX interrupt doesn't occur when address information of the received packet is not matched with device itself.	R/W	0
1	AUTO_CRC	When this field is set to '1', the RX interrupt doesn't occur when the CRC of the received packet is not valid.	R/W	
0		Reserved		0

### MACDSN (MAC DSN, 0x2192)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	MACDSN	If the DSN field of the received ACK packet is not equal to MACDSN, the RX interrupt does not occurred.	R/W	0

### SECCTRL (SECURITY CONTROL REGISTER, 0x2193)

Bit Field	Name	Descriptions	R/W	Reset Value																
7	SA_KEYSEL	Selects the KEY value for standalone SAES operation. When this field is '1', KEY1 is selected and when '0', KEY0 is selected.	R/W	0																
6	TX_KEYSEL	Selects the KEY value for AES operation during packet transmission. When this field is '1', KEY1 is selected and when '0', KEY0 is selected.	R/W	0																
5	RX_KEYSEL	Selects the KEY value for AES operation when packet reception. When this field is '1', KEY1 is selected and when '0', KEY0 is selected.	R/W	0																
4:2	SEC_M	In CBC-MAC operation, it represents the data length used in the authentication field in byte. <table border="1" data-bbox="544 1686 1070 1944"> <thead> <tr> <th>SEC_M</th> <th>Authentication field length</th> </tr> </thead> <tbody> <tr><td>1</td><td>4</td></tr> <tr><td>2</td><td>6</td></tr> <tr><td>3</td><td>8</td></tr> <tr><td>4</td><td>10</td></tr> <tr><td>5</td><td>12</td></tr> <tr><td>6</td><td>14</td></tr> <tr><td>7</td><td>16</td></tr> </tbody> </table>	SEC_M	Authentication field length	1	4	2	6	3	8	4	10	5	12	6	14	7	16	R/W	0x0
SEC_M	Authentication field length																			
1	4																			
2	6																			
3	8																			
4	10																			
5	12																			
6	14																			
7	16																			
1:0	SEC_MODE	Security mode. 0x0: No security	R/W	0x0																

		0x1: CBC-MAC mode 0x2: CTR mode 0x3: CCM mode		
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**TXL (AES OPERATION LENGTH FOR TRANSMIT PACKET REGISTER, 0x2194)**

Bit Field	Name	Descriptions	R/W	Reset Value
7		Reserved		0
6:0	TXL	<p>This field represents the length used in the AES operation for the packet to be transmitted. It has a different meaning for each security mode as follows.</p> <p>Security mode: CTR It represents the number of bytes between length byte and the data to be encrypted or decrypted of data in FIFO.</p> <p>Security mode: CBC-MAC It represents the number of byte between length byte and the data to be authenticated.</p> <p>Security mode: CCM It represents the length of data which is used not in encoding or decoding but in authentication.</p>	R/W	0x00

**RXL (AES OPERATION LENGTH FOR RECEIVED PACKET REGISTER, 0x2195)**

Bit Field	Name	Descriptions	R/W	Reset Value
7		Reserved		0
6:0	RXL	<p>This field represents the length used in the AES operation for the received packet and it has a different meaning for each security mode as follows.</p> <p>Security mode: CTR It represents the number of bytes between length byte and the data to be encrypted or decrypted of data in FIFO.</p> <p>Security mode: CBC-MAC It represents the number of bytes between length byte and the data to be authenticated.</p> <p>Security mode: CCM It represents the length of data which is used not in encoding or decoding but in authentication.</p>	R/W	0x00

**SECMAP (MAC/SECURITY REGISTER MAP SELECTION REGISTER, 0x219F)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:1		Reserved		0x00
0	SECMAP	MAC/security control/FIFO register map selection 0x0: MAC control / MAC FIFO selected 0x1: Security control / security FIFO selected	R/W	0

**9.1.1. Receive Mode**

When receiving the data from the PHY block, the MAC block stores the data in the RX FIFO. The data in the RX FIFO can be read by the MRFCPOP (0x2080) register. Data decryption is implemented by AES-128 algorithm, which supports CCM\* mode by ZigBee and CTR/CBC-MAC/CCM mode by IEEE 802.15.4. The RX Controller controls the process described above. When decrypting the data, the received frame data length is modified and the modified value is stored in the LSB of each frame by the hardware again.

The size of the RX FIFO is 256 bytes and it is implemented by a circular FIFO with a write pointer and a read pointer. The RX FIFO can store several frame data received from the PHY block. Since the LSB of each frame data represents the frame data length, it can be accessed by the write pointer and the read pointer.

When the data is received from the PHY block, the CRC information is checked to verify data integrity.

When AUTO\_CRC control bit of MACCTRL (0x2191) register is set to '1', CRC information is verified by the RX CRC block automatically. To check the result, refer to the CRC\_OK field of MACSTS (0x2180) register. When the value of CRC\_OK field is set to '1', there is no problem with CRC information. When the AUTO\_CRC control bit of the MACCTRL (0x2191) register is not set to '1', the CRC information should be verified by the software.

When a packet reception is completed in the PHY block, a PHY interrupt is sent to the MCU. In addition, when decryption operation is completed, an AES interrupt is sent to the MCU.

The following tables show the MAC RX FIFO control registers. Register address space is shared with the security-related register address space. Therefore, the MAC RX FIFO control registers are accessible when SECMAP is 0x0.

**MRFCPOP (MAC RX FIFO POP REGISTER, 0x2080)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	MRFCPOP	Through this register, data in RX FIFO is read.	R	

**MRFCWP (MAC RX FIFO WRITE POINTER REGISTER, 0x2081)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	MRFCWP	RX FIFO write pointer Total size of the write pointer is 9-bit with	R/W	0x00

		MRFCWP8 in MRFCSTS register. It is increased by '1' whenever data is written to the RX FIFO.		
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**MRFCRP (MAC RX FIFO READ POINTER REGISTER, 0x2082)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	MRFCRP	RX FIFO read pointer Total size of the read pointer is 9-bit with MRFCRP8 bit in MRFCSTS register. It is increased by '1' whenever data is read from the RX FIFO.	R/W	0x00

**MRFCCTRL (MAC RX FIFO CONTROL REGISTER, 0x2083)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:3		Reserved		0x0
2	ASA	When this field is set to '1', it automatically sets the starting address of a packet and the length of a packet decrypted by the AES engine to the information of the received packet.	R/W	1
1	ENA	When this field is set to '1', RX FIFO is enabled.	R/W	1
0	CLR	When this field is set to '1', MRFCWP, MRFCRP, MRFCSTS, MRFCSIZE registers are initialized.	R/W	0

**MRFCSTS (MAC RX FIFO STATUS REGISTER, 0x2084)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	MRFCWP8	Total size of the write pointer is 9-bit address with MRFCWP. This field is MSB, and is used to detect wrap around of a circular FIFO.	R/W	0
6	MRFCRP8	Total size of the read pointer is 9-bit address with MRFCRP. This field is MSB, and is used to detect wrap around of a circular FIFO.	R/W	0
5:2		Reserved	R	0x0
1	FULL	RX FIFO full This field is set to '1' when data size in RX FIFO is 256 byte.	R	0
0	EMPTY	RX FIFO empty This field is set to '1' when data size in RX FIFO is '0'.	R	0

**MRFCSIZE (NUMBER OF DATA IN MAC RX FIFO REGISTER, 0x2085)**

Bit Field	Name	Descriptions	R/W	Reset Value
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7:0	MRFCSIZE	This field represents the number of valid data bytes of RX FIFO. This field value is valid when the FIFO status is normal and is calculated by the difference between MRFCWP and MRFCRP.	R/W	0x00
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### 9.1.2. Transmit Mode

To transmit the data from a higher layer (MCU) to the PHY block, the device stores the data in the TX FIFO of the MAC block. When the MCU writes data in the MTFCPUSH (0x2000) register, data is stored in TX FIFO of MAC. The size of the TX FIFO is 256 byte and it is implemented by a circular FIFO with a write pointer and a read pointer. Since each data in TX FIFO is mapped to the memory area in the MCU, it can be written or read directly by the MCU.

The data stored in the TX FIFO can be transmitted to the PHY block by the TX request command of PCMD0 (0x2200) register. The TX controller controls the process described above. Data encryption is implemented by the AES-128 algorithm, which supports CCM\* mode by ZigBee and CTR/CBC-MAC/CCM mode by IEEE 802.15.4. The data length which is to be transmitted is stored in the LSB of each frame by the software when the frame data is stored in TX FIFO by the MCU. When the data in TX FIFO is encrypted, the data length is modified and then stored by the hardware again.

When transmitting the data in the TX FIFO, the CRC operation is processed to verify data integrity. When the AUTO\_CRC control bit of the MACCTRL (0x2191) register is set to '1', CRC information is generated by TX CRC block automatically. Otherwise, CRC operation should be operated by software.

When data encryption is completed, an AES interrupt is sent to the MCU. When the data transmission to the PHY block is completed, a PHY interrupt is sent to the MCU.

The following tables show the MAC TX FIFO control registers. Register address space is shared with the security-related register address space. Therefore, the MAC TX FIFO control registers are accessible when SECMAP is 0x0.

#### MTFCPUSH (MAC TX FIFO PUSH REGISTER, 0x2000)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	MTFCPUSH	When data is written to this register, it is stored in TX FIFO.	W	

#### MTFCWP (MAC TX FIFO WRITE POINTER REGISTER, 0x2001)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	MTFCWP	TX FIFO write pointer Total size of the write pointer is 9-bit with MTFCWP8 in MTFCSTS register. It is increased by '1' whenever data is written to the TX FIFO.	R/W	0x00

#### MTFCRP (MAC TX FIFO READ POINTER REGISTER, 0x2002)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	MTFCRP	TX FIFO read pointer Total size of the read pointer is 9-bit with MTFCRP8 bit in MTFCSTS register. It is increased by '1' whenever data is read from the TX FIFO.	R/W	0x00

#### MTFCCTRL (MAC TX FIFO CONTROL REGISTER, 0x2003)

Bit Field	Name	Descriptions	R/W	Reset Value
7:3		Reserved		0x0
2	ASA	When this field is set to '1', it automatically sets the starting address of a packet and the length of a packet encrypted by the AES engine to the information of the packet which is to be transmitted.	R/W	1
1	ENA	When this field is set to '1', TX FIFO is enabled	R/W	1
0	CLR	When this field is set to '1', the MFCWP, MFCRP, MFCSTS, MFCSIZE registers are initialized.	R/W	0

#### MTFCSTS (MAC TX FIFO STATUS REGISTER, 0x2004)

Bit Field	Name	Descriptions	R/W	Reset Value
7	MTFCWP8	Total size of the write pointer is 9-bit address with MFCWP. This field is MSB, and is used to detect wrap around of a circular FIFO.	R/W	0
6	MTFCRP8	Total size of the read pointer is 9-bit address with MFCRP. This field is MSB, and is used to detect wrap around of a circular FIFO.	R/W	0
5:2		Reserved	R	0x0
1	FULL	TX FIFO full This field is set to '1' when data size in TX FIFO is 256 byte.	R	0
0	EMPTY	TX FIFO empty This field is set to '1' when data size in TX FIFO is '0'.	R	0

#### MTFCSIZE (NUMBER OF DATA IN MAC TX FIFO REGISTER, 0x2005)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	MTFCSIZE	This field represents the number of valid data bytes of TX FIFO. This field value is valid when the FIFO status is normal and is calculated by the difference between MFCWP and MFCRP.	R/W	0x00

### 9.1.3. Data Encryption and Decryption

Data encryption or decryption is done by the security controller block. Security Controller consists of the block for processing encryption/decryption operation and the block for controlling.

In order to implement CCM\* mode by ZigBee and CTR/CBC-MAC/CCM mode by IEEE 802.15.4, 128-bit key value and a nonce are needed. MG2470 can have two 128-bit key values, KEY0 and KEY1. For encryption, the desired nonce value should be stored in the TX Nonce and KEY0 or KEY1 should be selected for use. For decryption, the desired nonce value should be stored in the RX Nonce and KEY0 or KEY1 should be selected for use. For more detailed information, refer to the IEEE802.15.4 standard document.

The following registers describe the security TX/RX FIFO control registers. They are accessible when SECMAP is 0x1.

#### STFCPUSH (SECURITY TX FIFO PUSH REGISTER, 0x2000)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	STFCPUSH	When data is written to this register, it is stored in security TX FIFO.	W	

#### STFCWP (SECURITY TX FIFO WRITE POINTER REGISTER, 0x2001)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	STFCWP	Security TX FIFO write pointer Total size of the write pointer is 9-bit with STFCWP8 in STFCSTS register. It is increased by '1' whenever data is written to the security TX FIFO.	R/W	0x00

#### STFCRP (SECURITY TX FIFO READ POINTER REGISTER, 0x2002)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	STFCRP	Security TX FIFO read pointer Total size of the read pointer is 9-bit with STFCRP8 in STFCSTS register. It is increased by '1' whenever data is read from the security TX FIFO.	R/W	0x00

#### STFCCTRL (SECURITY TX FIFO CONTROL REGISTER, 0x2003)

Bit Field	Name	Descriptions	R/W	Reset Value
7:2		Reserved		0x0
1	ENA	When this field is set to '1', security TX FIFO is enabled.	R/W	1
0	CLR	When this field is set to '1', STFCWP, STFCRP, STFCSTS, STFCSIZE	R/W	0



		registers are initialized.		
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**STFCSTS (SECURITY TX FIFO STATUS REGISTER, 0x2004)**

Bit Field	Name	Descriptions	R/W	Reset Value
7	STFCWP8	Total size of the write pointer is 9-bit address with STFCWP. This field is MSB, and is used to detect wrap around of a circular FIFO.	R/W	0
6	STFCRP8	Total size of the read pointer is 9-bit address with STFCRP. This field is MSB, and is used to detect wrap around of a circular FIFO.	R/W	0
5:2		Reserved	R	0x0
1	FULL	Security TX FIFO full This field is set to '1' when data size in security TX FIFO is 256 byte.	R	0
0	EMPTY	Security TX FIFO empty This field is set to '1' when data size in security TX FIFO is '0'.	R	0

**STFCSIZE (NUMBER OF DATA IN SECURITY TX FIFO REGISTER, 0x2005)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	STFCSIZE	This field represents the number of valid data bytes of security TX FIFO. This field value is valid when the FIFO status is normal and is calculated by the difference between STFCWP and STFCRP.	R/W	0x00

**STFCSECBASE (ENCRYPTION FRAME BASE ADDRESS REGISTER, 0x2007)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	STFCSECBASE	Frame base address for encryption	R/W	0x00

**STFCSECLN (ENCRYPTION FRAME LENGTH REGISTER, 0x2008)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	STFCSECLN	Frame length for encryption	R/W	0x00

**STFDMALN (DIRECT DATA TRANSFER SIZE REGISTER, 0x2009)**

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	STFDMALN	Data size of direct transfer between the security TX FIFO and the TX FIFO.	R/W	0x00

**STFDMACTRL (DIRECT DATA TRANSFER CONTROL REGISTER, 0x200A)**



Bit Field	Name	Descriptions	R/W	Reset Value
7:3		Reserved	R	0x00
2	DONE	This field is set to '1' when direct transfer between the TX security FIFO and the TX FIFO is done.	R	0
1	BUSY	When this field is set to '1', data transfer between the TX security FIFO and the TX FIFO is activated.	R	0
0	ENA	Enable the direct transfer between the security TX FIFO and the TX FIFO	W	0

#### SRFCPOP (SECURITY RX FIFO POP REGISTER, 0x2080)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	SRFCPOP	Through this register, data in security RX FIFO is read.	W	

#### SRFCWP (SECURITY RX FIFO WRITE POINTER REGISTER, 0x2081)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	SRFCWP	Security RX FIFO write pointer Total size of the write pointer is 9-bit with SRFCWP8 in SRFCSTS register. It is increased by '1' whenever data is written to the security RX FIFO.	R/W	0x00

#### SRFCRP (SECURITY RX FIFO READ POINTER REGISTER, 0x2082)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	SRFCRP	Security RX FIFO read pointer Total size of the read pointer is 9-bit with SRFCRP8 in SRFCSTS register. It is increased by '1' whenever data is read from the security RX FIFO.	R/W	0x00

#### SRFCCTRL (SECURITY RX FIFO CONTROL REGISTER, 0x2083)

Bit Field	Name	Descriptions	R/W	Reset Value
7:2		Reserved		0x0
1	ENA	When this field is set to '1', security RX FIFO is enabled.	R/W	1
0	CLR	When this field is set to '1', SRFCWP, SRFCRP, SRFCSTS, SRFCSIZE registers are initialized.	R/W	0

#### SRFCSTS (SECURITY RX FIFO STATUS REGISTER, 0x2084)

Bit	Name	Descriptions	R/W	Reset
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Field				Value
7	SRFCWP8	Total size of the write pointer is 9-bit address with SRFCWP. This field is MSB, and is used to detect wrap around of a circular FIFO.	R/W	0
6	SRFCRP8	Total size of the read pointer is 9-bit address with SRFCRP. This field is MSB, and is used to detect wrap around of a circular FIFO.	R/W	0
5:2		Reserved	R	0x0
1	FULL	Security RX FIFO full This field is set to '1' when data size in security RX FIFO is 256 byte.	R	0
0	EMPTY	Security RX FIFO empty This field is set to '1' when data size in security RX FIFO is '0'.	R	0

#### SRFCSIZE (NUMBER OF DATA IN SECURITY RX FIFO REGISTER, 0x2085)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	SRFCSIZE	This field represents the number of valid data bytes of security RX FIFO. This field value is valid when the FIFO status is normal and is calculated by the difference between SRFCWP and SRFCRP.	R/W	0x00

#### SRFCSECBASE (DECRYPTION FRAME BASE ADDRESS REGISTER, 0x2087)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	SRFCSECBASE	Frame base address for decryption	R/W	0x00

#### SRFCSECLN (DECRYPTION FRAME LENGTH REGISTER, 0x2088)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	SRFCSECLN	Frame length for decryption	R/W	0x00

#### SRFDMALEN (DIRECT DATA TRANSFER SIZE REGISTER, 0x2089)

Bit Field	Name	Descriptions	R/W	Reset Value
7:0	SRFDMALEN	Data size of direct transfer between the security RX FIFO and the RX FIFO.	R/W	0x00

#### SRFDMACTRL (DIRECT DATA TRANSFER CONTROL REGISTER, 0x208A)

Bit Field	Name	Descriptions	R/W	Reset Value
7:3		Reserved	R	0x00
2	DONE	This field is set to '1', when direct transfer between the security RX FIFO	R	0

		and the RX FIFO is done		
1	BUSY	When this field is set to '1', data transfer between the security RX FIFO and the RX FIFO is activated.	R	0
0	ENA	Enable the direct transfer between the security RX FIFO and the RX FIFO	W	0

## 9.2. PHY

The baseband PHY (a.k.a. modem) is composed of the O-QPSK modulator and demodulator with simple convolutional channel coder. [Figure 19] shows the baseband PHY structure.

The modulation starts from fetching the data in the TX MAC FIFO. The PHY payload (PHY service data unit; PSDU) can be optionally encoded with the convolutional channel encoder. After appending the preamble, SFD and length field to the PHY payload, a constructed frame (PHY protocol data unit; PPDU) is mapped to designated symbols according to the data-rate control of the PHY controller. Each symbol is accordingly spread by the DSSS chip modulator. The spread PHY bit stream in the chip-level is then modulated to the O-QPSK signal and transmitted by the RF transmitter. For the 250Kbps data-rate packet, its structure is fully compatible with the IEEE802.15.4 O-QPSK PHY specification.

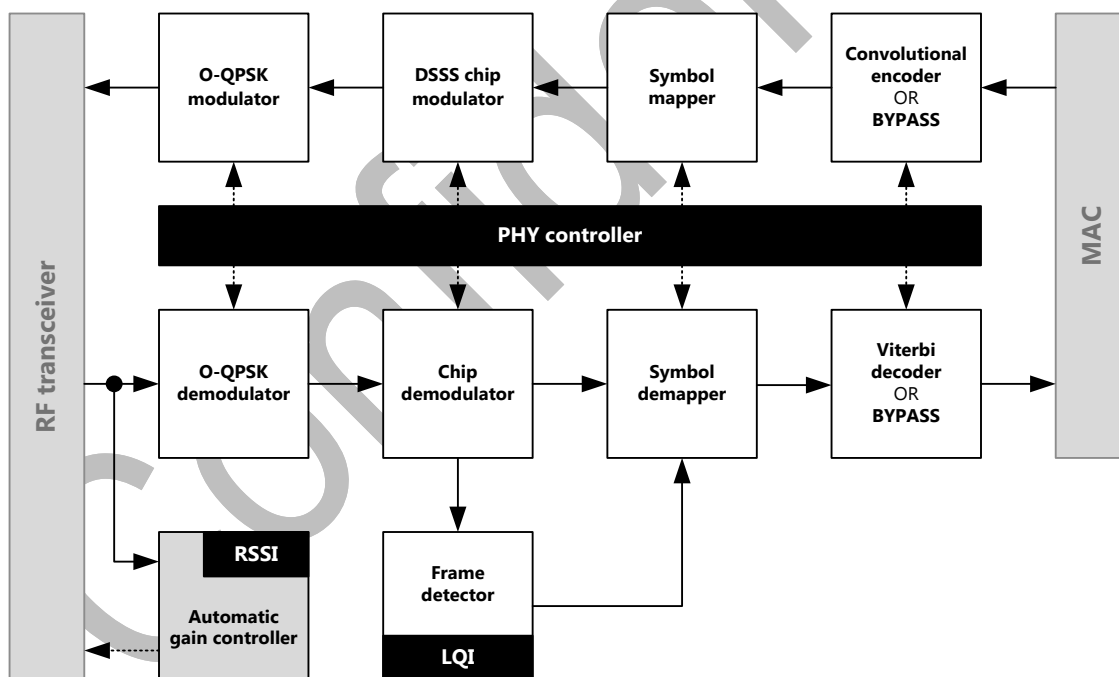


Figure 19. Baseband PHY

With the RF receiver, the received O-QPSK signal is demodulated to the chip sequences. The gain amplifying blocks in the RF receiver are controlled by the automatic gain controller (AGC). The chip sequence is appropriately de-spread by the chip demodulator, and then the start of the designated frame is determined by detecting the synchronization header (preamble and SFD). When the SFD is detected, the baseband PHY generates the interrupt which indicates the start of a packet.

The length and the PHY payload followed by the synchronization header are decoded by the

symbol demapper and Viterbi decoder (if the convolutional encoding is applied), and stored in the RX MAC FIFO. When the last data of the PHY payload is stored, the interrupt is generated to indicate the end of the packet reception. After a packet reception interrupt occurs, the RX MAC procedure is performed.

When a packet is received, the baseband PHY provides both of the received signal strength Indicator (RSSI) and the link quality indicator (LQI). They can be used to decide the quality of the communication channel.

While a packet does not exist, the baseband PHY continuously provides the RF channel energy level at antenna. The measured energy level is used to decide the communication channel state. Clear channel assessment (CCA) operation is based on this information. The CCA operation is used to prevent a collision when multiple users try to use a channel simultaneously. When a channel is determined to be busy, packet transmission is deferred until the channel state changes to idle.

### 9.2.1. Interrupt

The baseband PHY has 4 interrupt sources to notify the MCU of specific events.

- RX END (RXEND\_INT)

This interrupt notifies the MCU of the completion of a packet reception. When this interrupt has been generated, the received data in RX MAC FIFO can be handled. Also, the quality of the transmission channel can be checked by reading the RSSI/LQI registers.

- RX START (RXSTART\_INT)

This interrupt notifies the MCU of the start of a packet reception. (Note: It is not recommended to use RX START Interrupt normally.)

- TX END (TXEND\_INT)

This interrupt notifies the MCU of the end of a packet transmission. A new packet cannot be transmitted until a packet transmission is completed. When a communication channel is busy, a TX END Interrupt can be delayed until a communication channel goes to the idle state and the transmission is completed successfully.

- MODEM READY (MDREADY\_INT)

This interrupt notifies the MCU that the state of the baseband PHY has changed from the idle state to the ready state (either RX or TX) for requesting “modem ON”. The baseband PHY is in the idle state when the supply power is turned on, but needs to be changed to the ready state in order to transmit or receive the packet. This interrupt occurs when the RF transceiver has been stabilized by following the “modem ON” request.

- MODEM READY FAIL (MDREADYFAIL\_INT)

This interrupt notifies the MCU that the modem block has failed to change state from the idle state to the ready state. When the PLL in the RF transceiver is unlocked during dedicated time interval, this interrupt is generated and the state of the baseband PHY remains at the PLL setting state (although it is a transition state as shown in Figure 25).

The interrupt source can be identified through the INTSTS register. Some interrupt sources can be masked by setting the INTCON register. The baseband PHY also provides the

INTIDX register for indicating the interrupt source. The interrupt sources have priority: MDREADY\_INT (0) > TXEND\_INT (1) > RXSTART\_INT (2) > RXEND\_INT (3) > MDREADYFAIL\_INT (4). The INTIDX register indicates the highest-priority interrupt source among the present interrupts (not cleared). In order to clear the interrupt, it is sufficient to just read the INTIDX register and then the interrupt is cleared (one by one) in priority order.

### INTCLRSEQ (INTERRUPT CLEAR SEQUENCE REGISTER, 0x228C)

This register is used to set the sequence of interrupt clear.

Bit Field	Name	Descriptions	RW	Reset Value	
[7:5]	(Reserved)		R	0x0	
[4:0]	INTCLRSEQ	Interrupt clear sequence	R/W	0x00	
		bit			Description
		[0]			When this field is set to '1', the modem on interrupt is cleared by interrupt clear command.
		[1]			When this field is set to '1', the tx start interrupt is cleared by interrupt clear command.
		[2]			When this field is set to '1', the rx start interrupt is cleared by interrupt clear command.
		[3]			When this field is set to '1', the rx end interrupt is cleared by interrupt clear command.
[4]	When this field is set to '1', the modem on fail interrupt is cleared by interrupt clear command.				

### INTCON (PHY INTERRUPT CONTROL REGISTER, 0x228D)

This register is used to mask off the interrupt of baseband PHY.

Bit Field	Name	Descriptions	RW	Reset Value
7:5	(Reserved)			0x0
4	MDFAILMSK	This field masks MDFAIL_INT off. When MDFAILMSK field is set to '0', MDFAIL_INT interrupt is not generated.	R/W	0
3	RXENDMSK	This field masks RXEND_INT off. When RXENDMSK field is set to '0', RXEND_INT interrupt is not generated. This interrupt should be used to support the successful packet reception.	R/W	0
2	RXSTMSK	This field masks RXEND_START off. When RXSTMSK field is set to '0', RXSTART_INT interrupt is not generated. RXSTART_INT is not a mandatory interrupt. It is recommended to mask off RXSTART_INT interrupt when the rapid packet reception is needed.	R/W	0
1	TXENDMSK	This field masks TXEND_INT off. When TXENDMSK field is set to '0', TXEND_INT interrupt is not generated. This interrupt should	R/W	0

		be used to support the successful packet transmission.		
0	MDRDYMSK	This field masks MDRDY_INT off. When MRDYMSK field is set to '0', MDRDY_INT interrupt is not generated. This interrupt should be used to check whether a modem block is ready for transmission /reception or not.	R/W	0

### INTIDX (PHY INTERRUPT STATUS AND INDEX REGISTER, 0x228E)

This register is used to indicate the kinds of the interrupt when it occurs

Bit Field	Name	Descriptions	RW	Reset Value												
7:4		(Reserved)		0												
3	ALLINTCLR	This field disables all interrupts when they occur. This field clears all interrupts occurred. When multiple interrupts occur at the same time, the modem block stores them in a buffer and processes them in order. When INTIDX field is read, the executed interrupts are cleared in order. When ALLINTCLR field is set to '0', all the interrupts in buffer are cleared at the same time.	R/W	1												
2:0	INTIDX	This register shows the kind of the interrupt when an interrupt occurs, in order if multiple interrupts occur simultaneously. The INTSTS field in the INTSTS register should be used for looking through a list of all interrupts that have been triggered. After reading INTIDX field, executed interrupts are cleared automatically. <table border="1" data-bbox="491 1211 1126 1415"> <thead> <tr> <th>INTIDX</th> <th>Interrupt</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>MDRDY_INT interrupt</td> </tr> <tr> <td>1</td> <td>TXEND_INT interrupt</td> </tr> <tr> <td>2</td> <td>RXSTART_INT interrupt</td> </tr> <tr> <td>3</td> <td>RXEND_INT interrupt</td> </tr> <tr> <td>4</td> <td>MDFAIL_INT interrupt</td> </tr> </tbody> </table>	INTIDX	Interrupt	0	MDRDY_INT interrupt	1	TXEND_INT interrupt	2	RXSTART_INT interrupt	3	RXEND_INT interrupt	4	MDFAIL_INT interrupt		
INTIDX	Interrupt															
0	MDRDY_INT interrupt															
1	TXEND_INT interrupt															
2	RXSTART_INT interrupt															
3	RXEND_INT interrupt															
4	MDFAIL_INT interrupt															

### INTSTS (PHY INTERRUPT STATUS REGISTER, 0x228F)

This register is used to indicate the kinds of the interrupt when the multiple interrupts occur.

Bit Field	Name	Descriptions	RW	Reset Value										
7:5		(Reserved)		0										
4:0	INTSTS	Multiple interrupt status This register shows the interrupt status when multiple interrupts occur currently. Each bit in INTSTS field represents the status of a specific interrupt. A table of Bit vs. Interrupt is shown below. <table border="1" data-bbox="491 1861 1126 2033"> <thead> <tr> <th>Bit</th> <th>Description</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>MDRDY_INT interrupt</td> </tr> <tr> <td>1</td> <td>TXEND_INT interrupt</td> </tr> <tr> <td>2</td> <td>RXSTART_INT interrupt</td> </tr> <tr> <td>3</td> <td>RXEND_INT interrupt</td> </tr> </tbody> </table>	Bit	Description	0	MDRDY_INT interrupt	1	TXEND_INT interrupt	2	RXSTART_INT interrupt	3	RXEND_INT interrupt		
Bit	Description													
0	MDRDY_INT interrupt													
1	TXEND_INT interrupt													
2	RXSTART_INT interrupt													
3	RXEND_INT interrupt													

		4	MDFAIL_INT interrupt		
When an interrupt is triggered, the INTSTS field corresponding to each interrupt is set to '0'. To clear the executed interrupt, the bit for each of the executed interrupts should be reset to '1' by software.					

### 9.2.2. Data Rate

The MG2470 supports various data rate modes of 31.25Kbps ~ 1Mbps for applications beyond IEEE802.15.4 compliances. The data rate can be selected by using the MDMCNF register (SEL\_TXDR and FEC\_EN).

The 31.25Kbps ~ 1Mbps modes, which is listed in [Table 8], occupy 2MHz RF channel bandwidth which is the same as the IEEE 802.15.4-2.4GHz 250Kbps standard mode.

The 1Mbps data-rate mode is designed by applying the variable-rate convolutional coding with the same preamble structure as 250Kbps specified in IEEE802.15.4. The other data rate modes are designed by controlling the spreading factor.

**Table 8. Data rate modes**

Data Rate	FEC_EN	SEL_TXDR	Comment
1Mbps	0x1	0x0	
500Kbps	0x0	0x1	
250Kbps	0x0	0x2	IEEE802.15.4 compliant
125Kbps	0x0	0x3	
62.5Kbps	0x0	0x5	
31.25Kbps	0x0	0x9	

### 9.2.3. Forward Error Correction

Especially for higher data rate modes, the MG2470 uses the variable-rate convolutional channel coding for forward error correction (FEC). The MG2470 supports the convolution coding with the rates of 1/2, 2/3, and 3/4.

As shown in [Figure 20], the convolutional encoder with the constraint length of 5 is used for the mother convolutional encoder with the rate of 1/2.  $G1(x) = x^4 + x + 1$ .  $G2(x) = x^4 + x^3 + x^2 + 1$ . The rates of 2/3 and 3/4 are available by puncturing of the output of the mother convolutional encoder as shown in [Table 9].



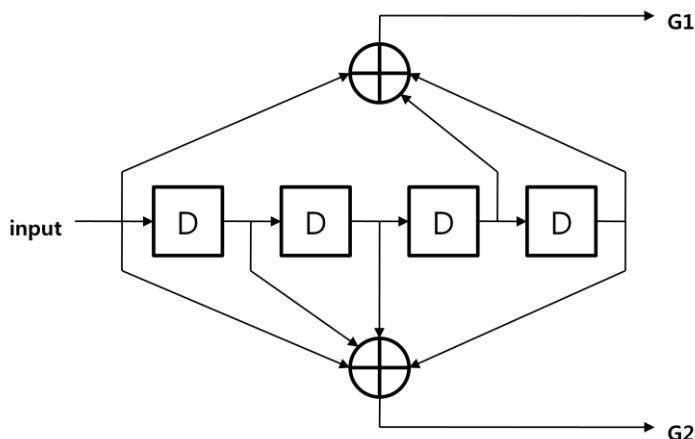


Figure 20. Convolutional encoder with rate of 1/2

Table 9. Puncturing pattern

Code rate	Puncturing matrix	Transmitted sequence
1/2	G1: 1 G2: 1	G1[0] G2[0]
2/3	G1: 1 0 G2: 1 1	G1[0] G2[0] G2[1]
3/4	G1: 1 0 1 G2: 1 1 0	G1[0] G2[0] G2[1] G1[2]

9.2.4. Packet Format

The MG2470 supports multiple data rates from 31.25Kbps to 1Mbps including 250Kbps specified in IEEE802.15.4. The packet format comparison for high data rates ( $\geq 250$ Kbps) with an example payload length of 60-Byte is shown in [Figure 21]. The period of the preamble, SFD, and LEN for 500Kbps, and 1Mbps data-rate modes are the same for 250Kbps mode. Only PHY payload interval is reduced.

The packet format comparison for low data rates ( $\leq 250$ Kbps) with an example payload length of 8-Byte is shown in [Figure 22].

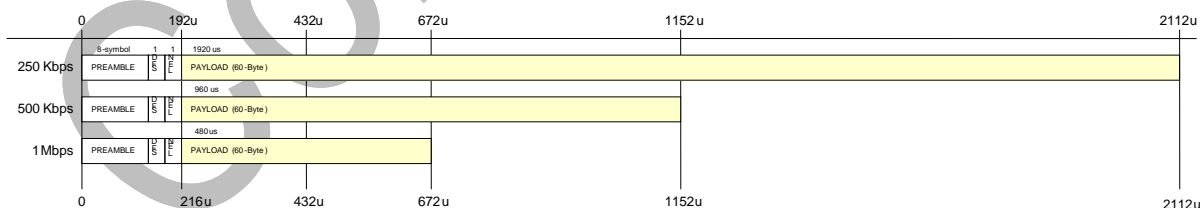


Figure 21. High data rate packet format

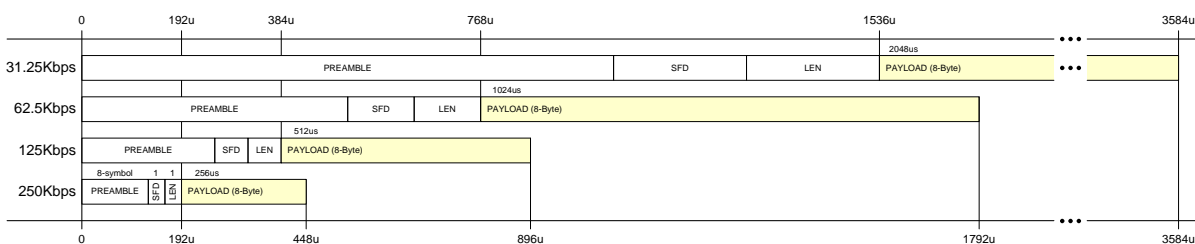


Figure 22. Low data rate packet format compared to the 250Kbps mode



**PCMD0 (PHY COMMAND0 REGISTER, 0x2200)**

This register is used to control the operation of baseband PHY.

Bit Field	Name	Descriptions	RW	Reset Value
[7:6]	(Reserved)	Only '0' allowed.	R/W	0
[5]	MODEM_OFF	When this field is set to '0', the baseband PHY status is changed to OFF. In the OFF state, the RF block is in a power-down state and the modem block is in the reset state. In this state, the MG2470 cannot receive or transmit packets. For the transmission or the reception of a packet, the baseband PHY needs to be changed to ON state. When the baseband PHY goes to OFF state, this field is set to '1' automatically by the hardware.	R/W	1
[4]	MODEM_ON	When this field is set to '0', the baseband PHY status is changed to ON. In ON state, the RF and baseband PHY are in the TX or RX ready state. In this state, the modem block controls power-down or power-up for the transmitter or the receiver without an active user application program. When the modem block goes to ON status, this field is set to '1' automatically by the hardware.	R/W	1
[3]	(Reserved)	Only '1' allowed.	R/W	1
[2]	TX_REQ	When this field is set to '0', the baseband PHY transmits a packet. When a packet transmission is requested, the baseband PHY changes to the TX ready state. Only when a communication channel is in idle state (CCA= '1'), will the packet be transmitted. When the channel is in busy state (CCA= '0'), the transmission is deferred until the channel state goes to idle. This field is set to '1' automatically by hardware after completing the transmission. When the packet transmission is completed successfully, a TXEND_INT interrupt is sent. If the packet transmission is abnormal, the interrupt is not sent and the TXREQ field is set to '1'.	R/W	1
[1:0]	(Reserved)	Only '0' allowed.	R/W	0

**PCMD1 (PHY COMMAND1 REGISTER, 0x2201)**

This register is used to control the operation of baseband PHY.

Bit Field	Name	Descriptions	RW	Reset Value
[7:2]	(Reserved)	Only '0' allowed.	R/W	0
[1]	TX_OFF	When this field is set to '1', the TX block is forced to be OFF regardless of the control of the baseband PHY state machine.	R/W	1
[0]	RX_OFF	When this field is set to '0', the RX block is forced to be OFF regardless of the control of the	R/W	1

		baseband PHY state machine.		
--	--	-----------------------------	--	--

### SETRATE (MODEM DATARATE CONTROL REGISTER, 0x2211)

This register is used to set data rate and FEC encoding.

Bit Field	Name	Descriptions	RW	Reset Value														
[7:6]	(Reserved)	Only '0' allowed.	R/W	0														
[5:4]	FEC_EN	Forward error correction encoding : 0x0 : UNCODING 0x1 : FEC code rate 1/2 0x2 : FEC code rate 2/3 0x3 : FEC code rate 3/4	R/W	0x0														
[3:0]	SEL_TXDR[3:0]	Used to select packet data rate  <table border="1"> <thead> <tr> <th>SEL_TXDR</th> <th>Data Rate</th> </tr> </thead> <tbody> <tr> <td>0x0</td> <td>1Mbps (with FEC_EN = 0x1)</td> </tr> <tr> <td>0x1</td> <td>500Kbps</td> </tr> <tr> <td>0x2</td> <td>250Kbps</td> </tr> <tr> <td>0x3</td> <td>125Kbps</td> </tr> <tr> <td>0x5</td> <td>62.5Kbps</td> </tr> <tr> <td>0x9</td> <td>31.25Kbps</td> </tr> </tbody> </table>	SEL_TXDR	Data Rate	0x0	1Mbps (with FEC_EN = 0x1)	0x1	500Kbps	0x2	250Kbps	0x3	125Kbps	0x5	62.5Kbps	0x9	31.25Kbps	R/W	0x6
SEL_TXDR	Data Rate																	
0x0	1Mbps (with FEC_EN = 0x1)																	
0x1	500Kbps																	
0x2	250Kbps																	
0x3	125Kbps																	
0x5	62.5Kbps																	
0x9	31.25Kbps																	

### 9.2.5. Clear Channel Assessment

While a packet does not exist, the baseband PHY continuously provides the RF channel energy level at antenna. As described before, the measured energy level is used to decide the communication channel state. Clear channel assessment (CCA) operation is based on this information. The CCA operation is used to prevent a collision when multiple users try to use a channel simultaneously. When a channel is determined to be busy, packet transmission is deferred until the channel state changes to idle.

### CCA0 (CLEAR CHANNEL ASSESSMENT0 REGISTER, 0X222C)

This register is used to set CCA operation environment.

Bit Field	Name	Descriptions	RW	Reset Value
[7:6]	(Reserved)	Only '0' allowed.	R/W	0
[5]	CCA_FIX	It fixes the communication channel state to idle. A communication channel state is determined by the CCA circuit in MG2470. When a channel state is busy, a packet is not transmitted. This field allows packet transmission regardless of the channel state. When this field is set to '1', the channel is always in idle state.	R/W	1
[4:2]	(Reserved)	Only '0' allowed.	R/W	0
[1:0]	CCAMD	This field sets the method to determine the communication channel state. The following describes the three methods to detect the channel state.  Energy detection (ED): This method determines the channel state as 'busy' when the energy of received signal is higher than the defined level.	R/W	0

		<p>Carrier detection (CD): This method determines the channel state as 'busy' when an IEEE802.15.4 carrier is detected.</p> <p>Frame detection (FD): This method determines the channel state as 'busy' when the normal IEEE802.15.4 packet is detected.</p> <table border="1"> <thead> <tr> <th>CCAMD</th> <th>Method</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>ED</td> </tr> <tr> <td>1</td> <td>CD</td> </tr> <tr> <td>2</td> <td>FD</td> </tr> <tr> <td>3</td> <td>reserved</td> </tr> </tbody> </table>	CCAMD	Method	0	ED	1	CD	2	FD	3	reserved		
CCAMD	Method													
0	ED													
1	CD													
2	FD													
3	reserved													

### CCA1 (CLEAR CHANNEL ASSESSMENT1 REGISTER, 0X222D)

This register is used to set CCA operation environment.

Bit Field	Name	Descriptions	RW	Reset Value
[7:0]	CCA1	This configures the CCA decision threshold when the energy detection method is used as that of the CCA detection.	R/W	0xB2

### 9.2.6. Link Quality Indicator

The MG2470 uses correlation results of multiple symbols in order to calculate an estimate of the LQI value. If LQI\_EN is "0x1", LQI estimation is automatically performed for every received frame except for FEC encoded packets. LQI values are integers ranging from 0 to 255 as required by the IEEE 802.15.4 standard.

After receiving 8 first symbols following the SFD, The MG2470 provide a correlation average value as a LQI. This is indicated by the LQI\_VALID register. The value can be obtained by means of register read.

### LQICNF0 (LQI CONTROL0 REGISTER, 0x227E)

This register is used to check LQI valid indicator.

Bit Field	Name	Descriptions	RW	Reset Value
[7]	LQI_VALID	LQI valid indicator :	R	0
[6:4]	Reserved	Only '0' allowed.	R/W	0x0
[3]	LQI_EN	LQI Enable Register 1 : Enable 0 : Disable	R/W	0
[2:0]	Reserved	Only '0' allowed.	R/W	0x0

### LQICNF1 (LQI CONTROL1 REGISTER,0x227F)

This register is LQI value which is computed with correlation value.

Bit Field	Name	Descriptions	RW	Reset Value
[7:0]	LQI	LQI value : 0~ 255	R	0x00

### 9.2.7. Received Signal Strength Indicator

When a packet is received, the baseband PHY provides both of the received signal strength Indicator (RSSI). The average energy level of the received RF signal at antenna is stored at AGCSTS2. The average energy level of the received packet is stored at AGCSTS3.

[Figure 23] shows typical measured RSSI plot over whole dynamic range. The typical dynamic range of the RSSI is about 80dB, and the accuracy is less than  $\pm 3$ dB.

#### AGCSTS2 (AGC STATUS2 REGISTER, 0x2284)

The stored energy level is the average of the received signal energy. The indicated value at AGCSTS2 register is stored as a 2's complement integer in dBm.

Bit Field	Name	Descriptions	RW	Reset Value
[7:0]	RXENRG	Average energy level of the received RF signal at antenna.	R	0x00

#### AGCSTS3 (AGC STATUS3 REGISTER, 0x2285)

While AGCSTS2 register indicates the average of received signal's energy level for a defined time interval, AGCSTS3 register shows the energy level of the last received packet. The value in AGCSTS3 register is retained until another packet is received.

Bit Field	Name	Descriptions	RW	Reset Value
[7:0]	PKTENRG	Average energy level of the received packet	R	0x00

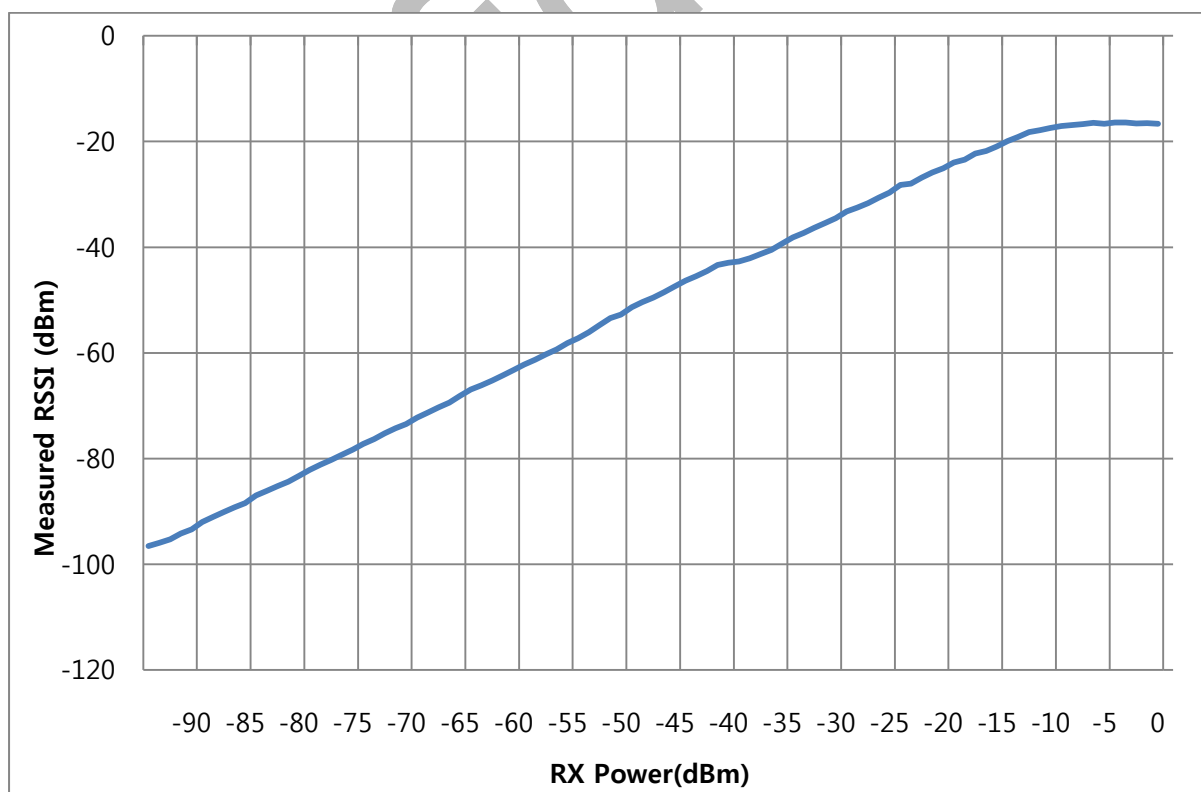


Figure 23. Measured RSSI (typical) versus RX input power

### 9.2.8. RADIO

A simplified block diagram with emphasis on RF and Analog front-end is shown in [Figure 24]. Since the bidirectional differential RF pins are used for RX and TX, no external T/R switch is required. In a receive path, a direct-conversion architecture is adopted. It operates in the 2.4GHz ISM band with excellent receiver sensitivity and robustness to interferers. Transmitter architecture is based on a direct-modulation technique using a direct RF frequency synthesis.

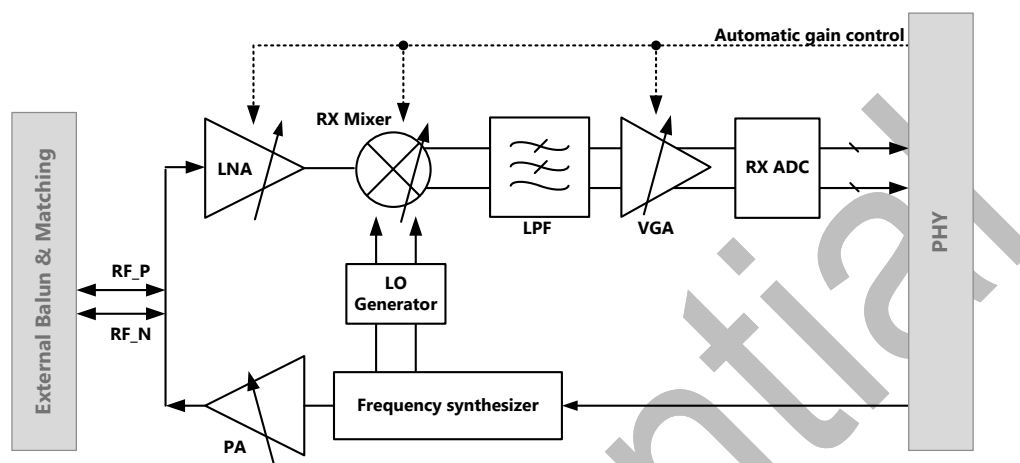


Figure 24. RF and Analog Block Diagram

The LNA amplifies the incoming received RF signal at RF\_P and RF\_N pins. The gain is controlled coarsely by the AGC block

The RX Mixer converts the RF signal to the baseband frequency in quadrature(I and Q). Also, the gain is controlled coarsely by the AGC block.

Channel filtering occurs in the LPF(low-pass filter). The VGA(variable-gain amplifier) provides sufficient gain, controlled by AGC, to drive the RX ADC(analog-to-digital converter).

The RX ADC converts the VGA output signals to the signed binary digital signals.

The frequency synthesizer(PLL) generates the carrier signals for channel frequency during reception and feeds the baseband modulation signals directly to the power amplifier during transmission. The center frequency of the desired channel can be adjusted by PLLFREQ register.

The LO generator transforms the differential outputs of the frequency synthesizer into the quadrature(I and Q) signals required for local signals in the RX Mixer.

The TX PA(power amplifier) amplifies the modulated RF signal from the PLL. The transmit power can be controlled by setting two registers of TXPA and TXDA.

In addition, external PA can be used with control pin(s) of TRSW and/or TRSWB. The TRSW and TRSWB is shared with GPIO P1[7] and P1[6] respectively. When MG2470 stays at the transmit mode, TRSW = 1. These pins are available by setting two registers of P1SRC\_SEL (SFR) and MONCON1.

#### PLLFREQ (CHANNEL CENTER FREQUENCY CONTROL REGISTER, 0x22BF)

This register is used to control the frequency of the frequency synthesizer for selecting the

desired channel.

Bit Field	Name	Descriptions	RW	Reset Value
[7]	(Reserved)	Only '0' allowed.	R/W	0
[6:0]	PLL_FREQ	Channel center frequency selection register $f_{\text{center}} = 2394 + \text{PLL\_FREQ (MHz)}$ The values of $5xN + 1$ where $N = 0, 1, \dots, 22$ are only valid as that of PLL_FREQ.	R/W	0x33

#### TXPA (TX PA CONTROL REGISTER, 0x22CE)

This register is used to control the gain of the transmit PA along with TXDA.

Bit Field	Name	Descriptions	RW	Reset Value
[7]	PABST_EN	When this field is set to '1', TX power is boosted up. Whereas the TX power can be increased, the current consumption is also increased.	R/W	0
[6:4]	(Reserved)	Only '0' allowed.	R/W	0x0
[3:0]	PA_GC	TX power amp control register As the register control value increases form 0x0 to 0xF, the power increases.	R/W	0xF

#### TXDA (TX DA CONTROL REGISTER, 0x22CF)

This register is used to control the gain of the transmit PA along with TXPA.

Bit Field	Name	Descriptions	RW	Reset Value
[7:5]	(Reserved)	Only '0' allowed.	R/W	0x0
[4:0]	DA_GC	TX power amp control register As the register control value increases form 0x0 to 0xF, the power increases.	R/W	0x1F

#### P1SRC\_SEL (GPIO 1 SOURCE CONTRL REGISTER, 0x9C (SFR))

This register is used to control the GPIO source

Bit Field	Name	Descriptions	RW	Reset Value
[7:0]	P1SRC_SEL	PORT-1 source control register. Each bit of port-1 can be mapped to the specific signal correspondingly. With this register control of P1SRC_SEL = 0xC0, the TRSW and TRSWB which are driven by baseband modem are available through P1[7] and P1[6] respectively.	R/W	0x00

#### MONCON1 (MONITOR CONTROL REGISTER1, 0x2291)

This register is used to generate the TRSW and TRSWB along with P1SRC\_SEL.

Bit Field	Name	Descriptions	RW	Reset Value
[7:0]	MONCON1	Currently, only 0x00 is allowd.This setting of 0x00 generates the TRSW and TRSWB through P1[7] and P1[6].	R/W	0x00

### 9.3. Operating Modes

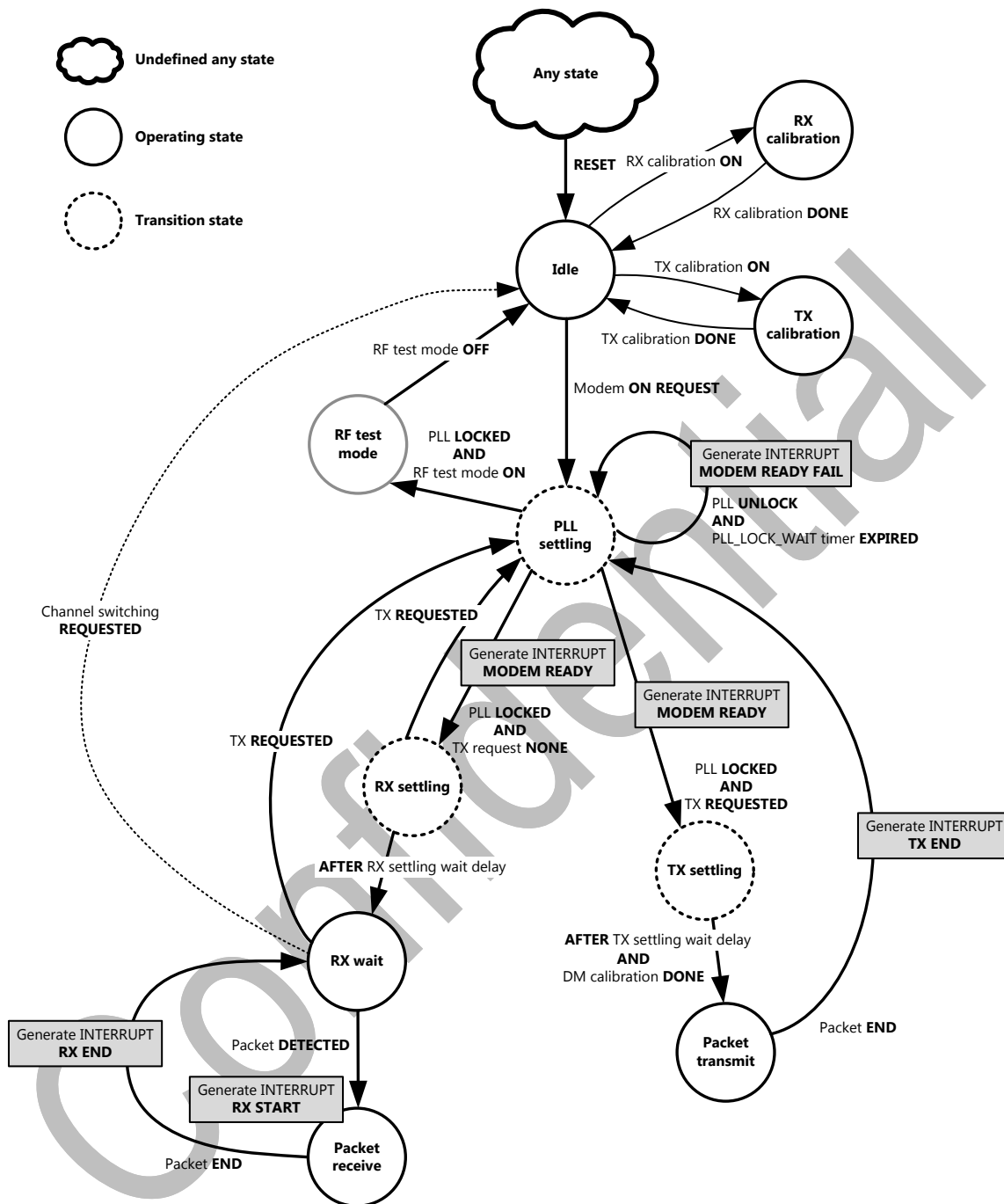


Figure 25 MG2470 State transition diagram

MG2470 PHY operation is controlled by the modem FSM shown in [Figure 25]. MG2470 PHY can be initialized by the reset. According to the control of the modem FSM, MG2470 operates in either packet transmitting or packet receiving mode. When the packet to be transmitted is prepared in TX MAC FIFO, MG2470 only operates in the packet transmit mode. Besides, it operates in the packet receiving mode and waits for the packet.

**Idle state:** MG2470 PHY can be initialized by the reset and the state of the modem FSM is moved to the idle state. In this state, the PHY executes no operation.



**RX calibration** state: In order to receive the packet correctly, the DC offset of the RF receiver should be calibrated before using it. Before MODEM ON is set, the DC offset of the RF receiver is preferred to be calibrated. When the DC calibration is initiated, the state is transited to RX calibration state. When the RX calibration has completed, the state is automatically transited to idle state. After the initial DC calibration is performed, the DC calibration tracker should be enabled.

**TX calibration** state: The modulation block of the RF transmitter should be also calibrated. Before MODEM ON is set, the TX modulator is preferred to be calibrated. When the TX calibration is initiated, the state is transited to TX calibration state. When the TX calibration has completed, the state is automatically transited to idle state.

**PLL settling** state: When the TX calibration is done, the RF synthesizer for channel selection can be configured and then the PLL (RF synthesizer) is started. Additionally, the PLL may be restarted in order to change the RX or TX channel. In the PLL settling state, the modem waits for the PLL to be locked. If the PLL is locked within designed time interval, the interrupt for MODEM READY is generated. Otherwise, the interrupt for MODEM READY FAIL is generated. This state is also a transition state. If the PLL is already locked (it can be clearly identified from the PLL lock detection flag), this state can be skipped.

**RF test mode** state: The RF test mode state is entered by setting the register as the RF test mode. When the PLL is locked and the RF test mode is set, the modem FSM changes its state from the PLL settling to the RF test mode state. Basically, in this state, the modem operates as the transmitter only. The modem FSM leaves this state to the idle state when the RF test mode becomes disabled.

**TX settling** state: When the PLL is locked and the packet transmission is requested (from MAC layer), the state of the modem FSM is changed from the PLL settling to the TX settling. In this state, the modem waits for the RF transmitter to be stable. The modem FSM stays at this state during the TX (settling) wait delay which can be configured.

**Packet transmit** state: After TX (settling) wait delay, the state of the modem FSM is transited to the packet transmit state. In this state, the modem transmits the packet in accordance to the PHY specification. When the packet transmission is completed, the state is moved to the PLL settling state along with generating the interrupt for TX END.

**RX settling** state: When the PLL is locked and no packet transmission is requested, the state of the modem FSM is changed from the PLL settling to the RX settling state in order to wait for packet coming from other transmitting units. In this state, the modem waits for the RF receiver to be stable. The modem FSM stays at this state during the RX (settling) wait delay which can be configured. If the packet transmission is requested when the state of the modem FSM stays at this state, the modem FSM changes its state from the RX settling to the PLL settling state.

**RX wait** state: After RX (settling) wait delay, the state of the modem FSM is transited to the RX wait state. In this state, the modem waits for the packet reception. When the packet is detected, the state is moved to the packet receive state along with generating the interrupt for RX START. If the packet transmission is requested when the state of the modem FSM stays at this state, the modem FSM changes its state from the RX wait to the PLL settling state.

**Packet receive** state: When the packet is detected at the RX wait state, the state of the modem FSM is moved to the packet receive state. In this state, the modem receives the packet and puts its payload to RX MAC FIFO. At the end of the packet, the state is transited to the RX wait state along with generating the interrupt for RX END.



## 10. IN-SYSTEM PROGRAMMING (ISP)

The in-system programming (ISP) function enables a user to download an application program to the internal flash memory. When it is power-on, the MG2470 checks the value of MS[2:0] pin. When the value of the MS[2] pin is '1' and the value of the MS[1:0] is '0', ISP mode is selected. The following procedure is to use the ISP function.

1. In MS[2:0] pin, MS[2] should be set to '1'. MS[1] and MS[0] should be set to '0'.
2. Make RS-232 connection with the PC by using the serial port or the USB-to-Serial adapter. The configuration is 8-bit, no parity, 1 stop bit and 115200 baud rate.
3. Power up the device.
4. Execute the ISP Host program on PC. (It is included in Development Kit)
5. Load an application program in Intel HEX format.
6. Download.

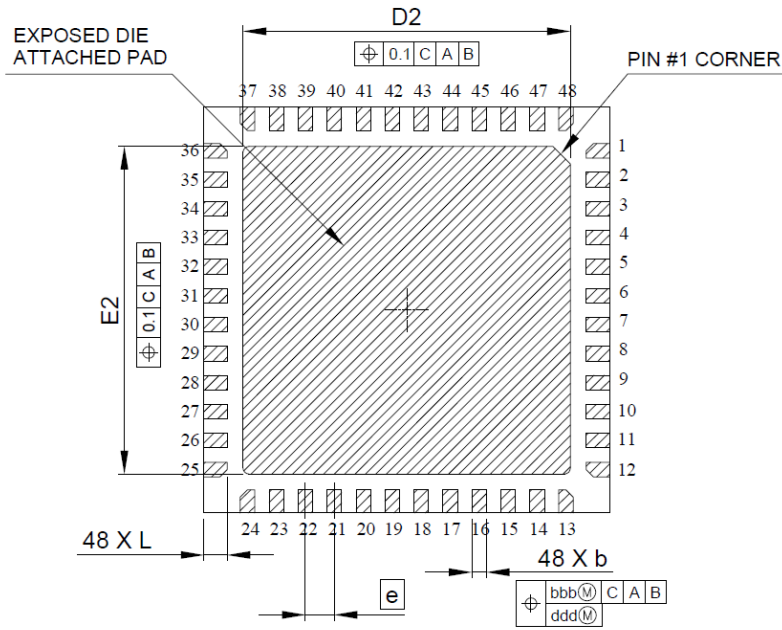
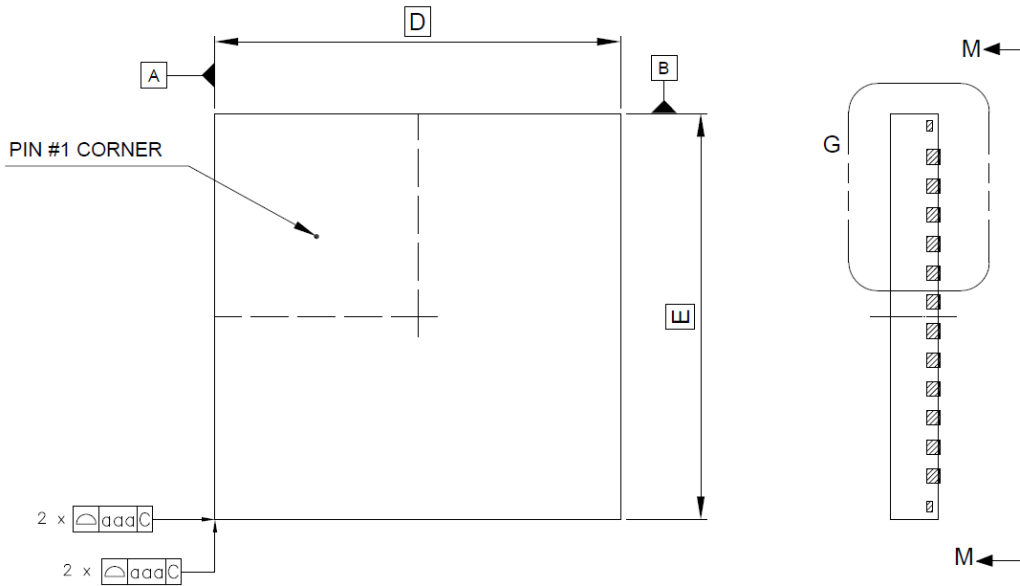
**\*Notice : The P0[6] pin should not be set to 0 for the normal ISP operation.**

When the procedure is finished, an application program is stored in the internal flash memory. To execute the application program, a device should be reset after setting MS[2:0] pin to '0'.

After reset, the application program in the internal flash memory is executed by the internal MCU.

# 11. PACKAGE INFORMATION

## 11.1. MG2470-F48 Dimensions (QFN 48-pin)



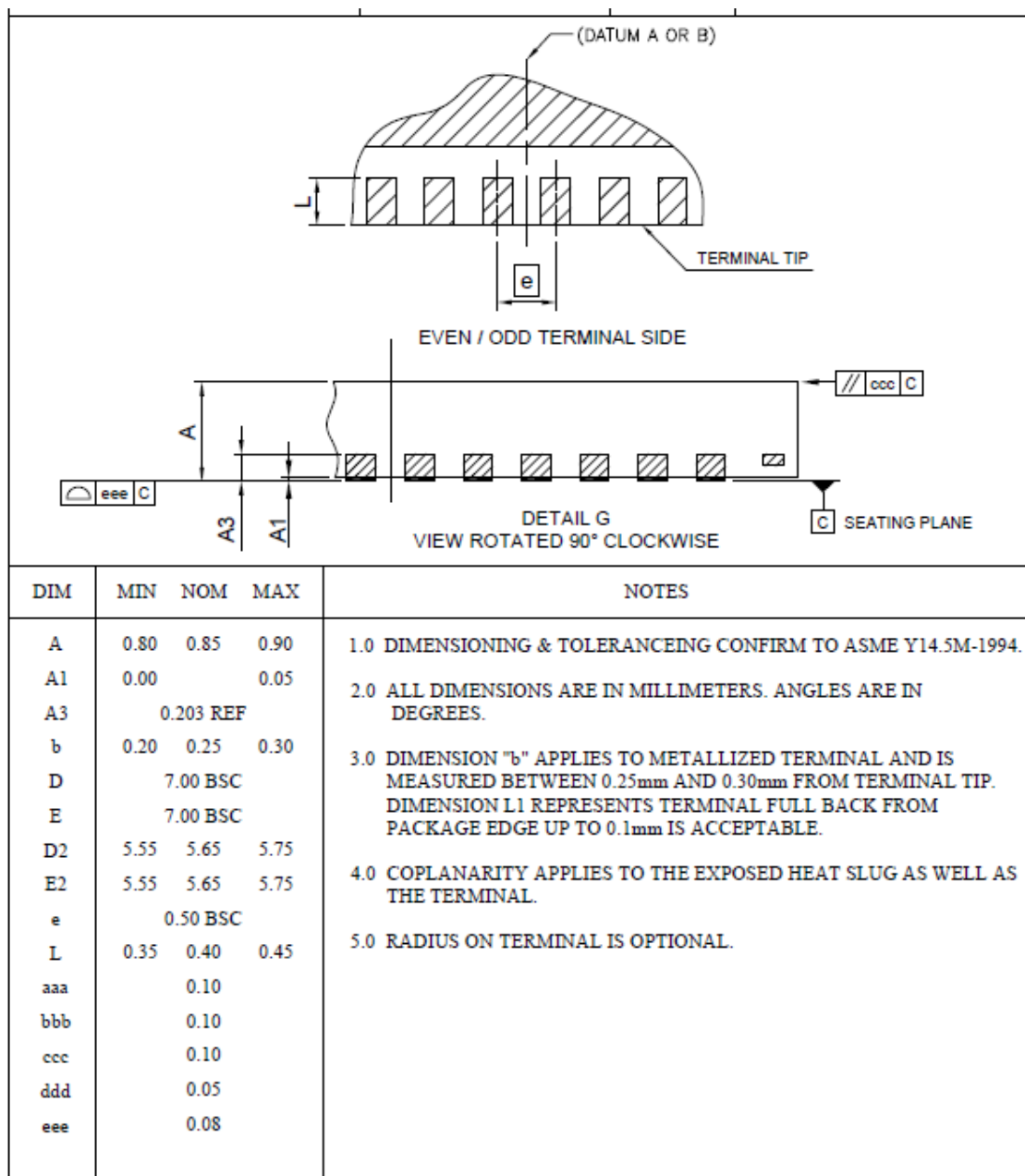


Figure 26. Package Drawing-QFN48

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[sales@radiopulse.co.kr](mailto:sales@radiopulse.co.kr)

**About RadioPulse Inc.**

**RadioPulse** is a Being Wireless solution provider offering wireless communication & network technologies and developing next generation wireless networking technologies.

The new wireless networking solutions envisioned by RadioPulse will enable user to enjoy wireless technologies with easy interface.

Founded in April of 2003, the company maintains it headquarters and R&D center in Seoul, Korea.

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