

## MCS3142 Dual KEELOQ<sup>®</sup> Technology Encoder Data Sheet

### Features Overview:

#### SECURITY

- Ultimate KEELOQ<sup>®</sup> Technology:
  - Programmable 32-bit serial number
  - AES-128 block cipher
  - Programmable 128-bit crypt key
  - Timekeeping based on external 32.768 kHz crystal
  - 192-bit transmission code length:
    - 32-bit unencrypted portion
    - 128-bit encrypted, hopping code portion
    - 32-bit authorization check
- Classic KEELOQ Technology:
  - Programmable 28-bit serial number
  - Data based on Classic KEELOQ Technology:
    - KEELOQ technology 32-bit block cipher
    - Programmable 64-bit crypt key
    - KEELOQ technology secure learn
    - Programmable 60-bit seed value
  - 66-bit transmission code length:
    - 34-bit unencrypted portion
    - 32-bit encrypted, hopping code portion
- Operating Features:
  - 1.8 to 3.6V operation
  - Four switch inputs
  - 15 functions available
  - Configurable button modes
  - One active-low LED drive
  - Configurable minimum code word completion
- RF:
  - Configurable bit rate
  - Configurable modulation, supporting FSK and OOK
  - Configurable data modulation, supporting PWM and Manchester
- Other:
  - Button inputs have internal pull-up resistors
  - LED output

### Typical Applications:

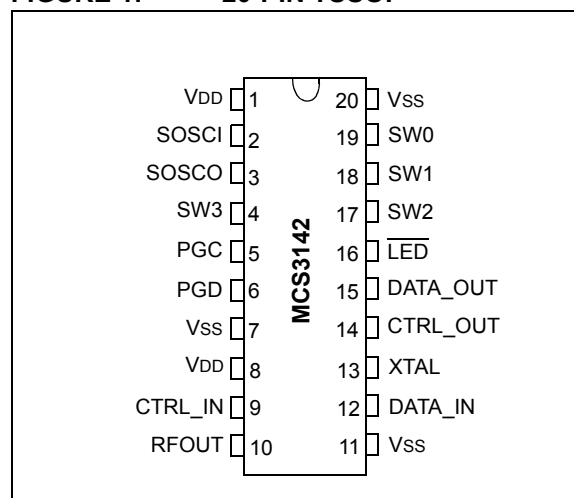
MCS3142 is ideal for Remote Keyless Entry (RKE) applications. These applications include:

- Automotive RKE Systems
- Automotive Alarm Systems
- Gate and Garage Door Openers
- Home Security Systems
- Security and Safety Sensors
- Remote Control
- Remote Keypad
- Wireless Sensors

### Package Type:

- 20-pin TSSOP

**FIGURE 1: 20-PIN TSSOP**



**TABLE 1: PIN DESCRIPTION**

| Name     | 20-Pin TSSOP | Input Type | Output Type | Description                      |
|----------|--------------|------------|-------------|----------------------------------|
| VDD      | 1            | Power      | —           | Power                            |
| SOSCI    | 2            | Analog     | —           | Secondary Oscillator             |
| SOSCO    | 3            | Analog     | —           | Secondary Oscillator             |
| SW3      | 4            | TTL        | —           | Switch 3 Input                   |
| PGC      | 5            | TTL        | —           | Programming Clock                |
| PGD      | 6            | TTL        | TTL         | Programming Data                 |
| —        | 7            | —          | —           | No Connection; Tie to Vss        |
| VDD      | 8            | Power      | —           | Power                            |
| CTRL_IN  | 9            | TTL        | —           | Transmitter Clock                |
| RFOUT    | 10           | —          | RF          | Transmitter Output               |
| Vss      | 11           | Power      | —           | Power                            |
| DATA_IN  | 12           | TTL        | —           | Transmitter Data                 |
| XTAL     | 13           | Analog     | —           | Transmitter Reference Oscillator |
| CTRL_OUT | 14           | —          | TTL         | Transmitter Clock                |
| DATA_OUT | 15           | —          | TTL         | Transmitter Data                 |
| LED      | 16           | —          | TTL         | LED Output (active-low)          |
| SW2      | 17           | TTL        | —           | Switch 2 Input                   |
| SW1      | 18           | TTL        | —           | Switch 1 Input                   |
| SW0      | 19           | TTL        | —           | Switch 0 Input                   |
| Vss      | 20           | Power      | —           | Power                            |

## Table of Contents

|      |                                            |    |
|------|--------------------------------------------|----|
| 1.0  | General Description .....                  | 4  |
| 2.0  | Device Description .....                   | 6  |
| 3.0  | Memory Organization .....                  | 7  |
| 4.0  | Classic KEELoQ® Operation .....            | 16 |
| 5.0  | Ultimate KEELoQ Operation .....            | 18 |
| 6.0  | Transmitter Operation .....                | 21 |
| 7.0  | Device Operation .....                     | 25 |
| 8.0  | Integrating MCS3142 into a System .....    | 27 |
| 9.0  | Electrical Specifications .....            | 29 |
| 10.0 | Packaging Information .....                | 30 |
|      | The Microchip Web Site .....               | 34 |
|      | Customer Change Notification Service ..... | 34 |
|      | Customer Support .....                     | 34 |
|      | Product Identification System .....        | 35 |

## TO OUR VALUED CUSTOMERS

It is our intention to provide our valued customers with the best documentation possible to ensure successful use of your Microchip products. To this end, we will continue to improve our publications to better suit your needs. Our publications will be refined and enhanced as new volumes and updates are introduced.

If you have any questions or comments regarding this publication, please contact the Marketing Communications Department via E-mail at [docerrors@microchip.com](mailto:docerrors@microchip.com). We welcome your feedback.

### Most Current Data Sheet

To obtain the most up-to-date version of this data sheet, please register at our Worldwide Web site at:

<http://www.microchip.com>

You can determine the version of a data sheet by examining its literature number found on the bottom outside corner of any page. The last character of the literature number is the version number, (e.g., DS30000000A is version A of document DS30000000).

### Errata

An errata sheet, describing minor operational differences from the data sheet and recommended workarounds, may exist for current devices. As device/documentation issues become known to us, we will publish an errata sheet. The errata will specify the revision of silicon and revision of document to which it applies.

To determine if an errata sheet exists for a particular device, please check with one of the following:

- Microchip's Worldwide Web site; <http://www.microchip.com>
- Your local Microchip sales office (see last page)

When contacting a sales office, please specify which device, revision of silicon and data sheet (include literature number) you are using.

### Customer Notification System

Register on our web site at [www.microchip.com](http://www.microchip.com) to receive the most current information on all of our products.

## 1.0 GENERAL DESCRIPTION

MCS3142 is a dual encoder, designed for secure Remote Keyless Entry (RKE) and secure remote control systems. MCS3142 utilizes both the Classic KEELoQ code hopping technology and the new Ultimate KEELoQ technology time-stamping solution. Both of these encoders incorporate high security, a small package outline and low cost to make this device a perfect solution for unidirectional authentication systems and access control systems.

Classic KEELoQ technology combines a hopping code generated by a nonlinear encryption algorithm, a serial number and Status bits to create a secure transmission code. The length of the transmission eliminates the threat of code scanning and code grabbing access techniques.

Ultimate KEELoQ technology is generated using the industry standard AES-128 encryption algorithm, a serial number and a timer-driven message counter which continuously increments, independent of events, to provide a better, more secure solution. The timekeeping functionality protects against jam-and-replay attack techniques.

The crypt key, serial number and configuration data are stored in an EEPROM array which is not accessible via any external connection. The EEPROM data is programmable but read-protected. The data can be verified only after an automatic erase and programming operation. This protects against attempts to gain access to keys or manipulate synchronization values. In addition, MCS3142 provides an easy to use serial interface for programming the necessary keys, system parameters and configuration data.

### 1.1 Key Terms

The following is a list of key terms used throughout this data sheet. For additional information on KEELoQ technology and code hopping, refer to “*An Introduction to KEELoQ® Code Hopping*” Technical Brief (DS91002).

- **RKE:** Remote Keyless Entry
- **Function Code:** It indicates what button input(s) activated the transmission. It encompasses the function code bits.
- **Code Hopping:** A method by which a code, viewed externally to the system, appears to change unpredictably each time it is transmitted
- **Code Word:** A block of data that is repeatedly transmitted upon button activation
- **Transmission:** A data stream consisting of repeating code words

- **Crypt Key:** A unique and secret number (64-bit for Classic KEELoQ technology, 128-bit for Ultimate KEELoQ technology) used to encrypt and decrypt data. In a symmetrical block cipher such as those used on MCS3142, the encryption and decryption keys are equal and, therefore, will generally be referred to as the crypt key.
- **Encoder:** A device that generates and encodes data
- **Encryption Algorithm:** A method whereby data is scrambled using a crypt key. The data can only be interpreted by the respective decryption algorithm using the same crypt key.
- **Decoder:** A device that decodes data received from an encoder
- **Decryption Algorithm:** A recipe whereby data, scrambled by an encryption algorithm, can be unscrambled using the same crypt key
- **Time-Stamp:** The time-derived value recorded with a message
- **Learn:** Learning involves the receiver calculating the transmitter's appropriate crypt key, decrypting the received hopping code and storing the serial number, synchronization counter or timer value, and crypt key in EEPROM. The KEELoQ technology product family facilitates several learning strategies to be implemented on the decoder. The following are examples of what can be done:
  - **Simple Learning:** The receiver uses a fixed crypt key. The crypt key is common to every component used by the same manufacturer.
  - **Normal Learning:** The receiver derives a crypt key from the encoder serial number. Every transmitter has a unique crypt key.
  - **Secure Learning:** The receiver derives a crypt key from the encoder seed value. Every encoder has a unique seed value that is only transmitted by a special button combination.
- **Manufacturer's Code:** A unique and secret number (64-bit for Classic KEELoQ technology, 128-bit for Ultimate KEELoQ technology) used to derive crypt keys. Each encoder is programmed with a crypt key that is a function of the manufacturer's code. Each decoder is programmed with the manufacturer's code itself.

The MCS3142 code hopping encoder is designed specifically for keyless entry systems. Typical applications include vehicles and home garage door openers. The encoder portion of a keyless entry system is integrated into a transmitter carried by the user. The transmitter is operated to gain access to a vehicle or a restricted area. MCS3142 is meant to be a cost-effective, yet secure solution to such systems, requiring very few external components (see [Figure 2-1](#)).

Most low-end keyless entry transmitters are given a fixed identification code that is transmitted every time a button is pushed. The number of unique identification codes in a low-end system is usually a relatively small number. These shortcomings provide an opportunity for a sophisticated thief to create a device that 'grabs' a transmission and retransmits it later, or a device that quickly 'scans' all possible identification codes until the correct one is found.

MCS3142, on the other hand, employs both the Classic and Ultimate KEELOQ code hopping technology. The high-security level of MCS3142 is based on the patented KEELOQ technology.

For Classic KEELOQ technology, a block cipher based on a block length of 32 bits and a key length of 64 bits is used. The algorithm obscures the information in such a way that if a single hopping code data bit changes (before encryption), statistically more than 50% of the encrypted data bits will change.

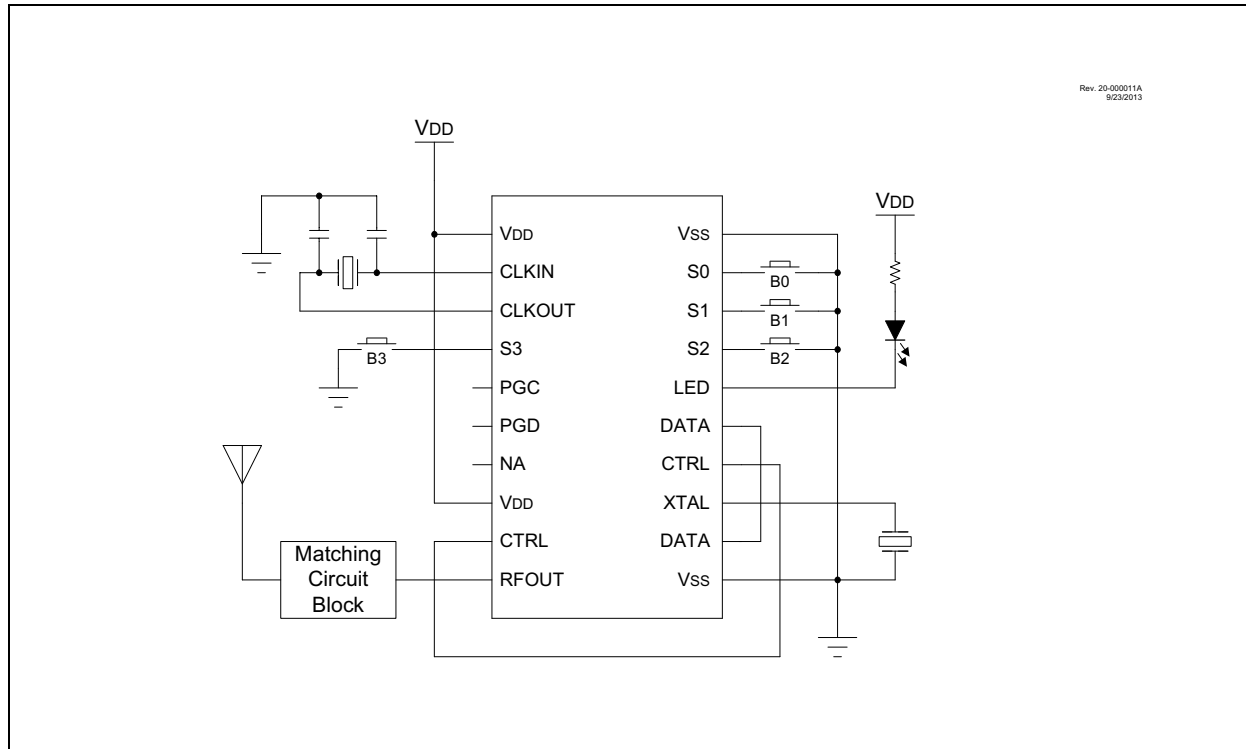
Ultimate KEELOQ technology uses the industry standard AES-128 encryption algorithm to obscure data using 128 bits for both its block and key length. In addition to the security of Classic KEELOQ technology, Ultimate KEELOQ technology sends a time-stamp as part of the transmission. This can prevent other more sophisticated attacks such as the 'jam-and-relay' attack.

# MCS3142

## 2.0 DEVICE DESCRIPTION

As shown in the typical application circuit (Figure 2-1), MCS3142 is a simple device to use. It requires only the addition of buttons, an external 32.768 kHz watch crystal, a transmitter reference oscillator, and RF circuitry for use as the transmitter in your security application. See Table 1 for a description of each pin.

**FIGURE 2-1: TYPICAL CIRCUIT**



### 3.0 MEMORY ORGANIZATION

MCS3142 has 128 bytes of configuration data. In general, the Configuration bytes can be divided into three categories: those options related to the Classic KEELOQ technology encoder, those options related to the Ultimate KEELOQ technology encoder, and those options related to the transmitter and device operation shared by the two encoders.

**TABLE 3-1: CONFIGURATION REGISTERS**

| Address   | Size (Bytes) | Description                                                    |
|-----------|--------------|----------------------------------------------------------------|
| 0x00-0x07 | 8            | Classic KEELOQ® Technology Crypt Key                           |
| 0x08-0x0F | 8            | Classic KEELOQ Technology Seed Value                           |
| 0x10-0x13 | 4            | Classic KEELOQ Technology Serial Number                        |
| 0x14-0x15 | 2            | Classic KEELOQ Technology DISC Value                           |
| 0x16-0x17 | 2            | Classic KEELOQ Technology Encoder Configuration                |
| 0x18-0x19 | 2            | Classic KEELOQ Technology Transmitter Configuration            |
| 0x1A      | 1            | Classic KEELOQ Technology Minimum Packet                       |
| 0x1B-0x1C | 2            | Classic KEELOQ Technology Maximum Packet                       |
| 0x1D      | 1            | Classic KEELOQ Technology Time Element PR2 Value               |
| 0x1E-0x2D | 16           | Ultimate KEELOQ Technology Crypt Key                           |
| 0x2E-0x3D | 16           | Ultimate KEELOQ Technology Seed Value                          |
| 0x3E-0x41 | 4            | Ultimate KEELOQ Technology Serial Number                       |
| 0x42-0x43 | 2            | Reserved                                                       |
| 0x44-0x53 | 16           | Ultimate KEELOQ Technology Authorization Code                  |
| 0x54-0x55 | 2            | Ultimate KEELOQ Technology Encoder Configuration               |
| 0x56-0x57 | 2            | Ultimate KEELOQ Technology Transmitter Configuration           |
| 0x58      | 1            | Ultimate KEELOQ Technology Minimum Packet                      |
| 0x59-0x5A | 2            | Ultimate KEELOQ Technology Maximum Packet                      |
| 0x5B      | 1            | Ultimate KEELOQ Technology Time Element PR2 Value              |
| 0x5C-0x5E | 3            | Encoder Frequency Setting                                      |
| 0x5F-0x60 | 2            | Encoder Button Configuration                                   |
| 0x61-0x62 | 2            | Seed Packet Button Configuration                               |
| 0x63-0x65 | 3            | Ultimate KEELOQ Technology Synchronization Counter, Copy 1     |
| 0x66      | 1            | Ultimate KEELOQ Technology Synchronization Counter CRC, Copy 1 |
| 0x67-0x68 | 2            | Classic KEELOQ Technology Synchronization Counter, Copy 1      |
| 0x69      | 1            | Classic KEELOQ Technology Synchronization Counter CRC, Copy 1  |
| 0x6A-0x6B | 2            | Ultimate KEELOQ Technology Reset Counter, Copy 1               |
| 0x6C      | 1            | Ultimate KEELOQ Technology Reset Counter CRC, Copy 1           |
| 0x6D-0x70 | 4            | Ultimate KEELOQ Technology Low-Speed Timer, Copy 1             |
| 0x71      | 1            | Ultimate KEELOQ Technology Low-Speed Timer CRC, Copy 1         |
| 0x72-0x74 | 3            | Ultimate KEELOQ Technology Synchronization Counter, Copy 2     |
| 0x75      | 1            | Reserved                                                       |
| 0x76-0x77 | 2            | Classic KEELOQ Technology Synchronization Counter, Copy 2      |
| 0x78      | 1            | Reserved                                                       |
| 0x79-0x7A | 2            | Ultimate KEELOQ Technology Reset Counter, Copy 2               |
| 0x7B      | 1            | Reserved                                                       |
| 0x7C-0x7F | 4            | Ultimate KEELOQ Technology Timer, Copy 2                       |

## 3.1 Counter and Timer Protection

Because they are written during normal operation of the device, the two synchronization counters, Reset counter and time value receive special protection to guard against data loss from unexpected power loss. An 8-bit CRC is calculated and stored alongside each variable. Further, each variable is duplicated in a different portion of memory. Whenever a value is read, the CRC is calculated and verified against the stored value. If there is a mismatch, the second copy of the data is read instead. The CRC calculation uses a polynomial represented by  $x^8 + x^4 + x^3 + x^2 + 1$ .

[Example 3-1](#) describes a sample C function to compute this value.

### EXAMPLE 3-1: CRC CALCULATION

```
static uint8_t crc(const uint8_t* buffer, size_t len){
    uint8_t bitcount;
    uint8_t c = 0xFF;

    while(len--) {
        c ^= *buffer++;

        for(bitcount = 0; bitcount < 8; bitcount++){
            if((c & 0x80) != 0) {
                c <<= 1;
                c ^= 0x1D;
            }else{
                c <<= 1;
            }
        }
    }

    return ~c;
}
```



### 3.2 Configuration Byte Details

The following tables describe Configuration bytes in detail.

**TABLE 3-2: CLASSIC KEELoQ® TECHNOLOGY CRYPT KEY CONFIGURATION REGISTERS**

| Byte Address | Bit | Description | Values                                        |
|--------------|-----|-------------|-----------------------------------------------|
| 0x00         | 7:0 | Crypt Key   | Least Significant eight bits of the crypt key |
| 0x01         | 7:0 |             | Byte 1 of the crypt key                       |
| 0x02         | 7:0 |             | Byte 2 of the crypt key                       |
| 0x03         | 7:0 |             | Byte 3 of the crypt key                       |
| 0x04         | 7:0 |             | Byte 4 of the crypt key                       |
| 0x05         | 7:0 |             | Byte 5 of the crypt key                       |
| 0x06         | 7:0 |             | Byte 6 of the crypt key                       |
| 0x07         | 7:0 |             | Most Significant eight bits of the crypt key  |

**TABLE 3-3: CLASSIC KEELoQ® TECHNOLOGY SEED CONFIGURATION REGISTERS**

| Byte Address | Bit | Description | Values                                   |
|--------------|-----|-------------|------------------------------------------|
| 0x08         | 7:0 | Seed        | Least Significant eight bits of the seed |
| 0x09         | 7:0 |             | Byte 1 of the seed                       |
| 0x0A         | 7:0 |             | Byte 2 of the seed                       |
| 0x0B         | 7:0 |             | Byte 3 of the seed                       |
| 0x0C         | 7:0 |             | Byte 4 of the seed                       |
| 0x0D         | 7:0 |             | Byte 5 of the seed                       |
| 0x0E         | 7:0 |             | Byte 6 of the seed                       |
| 0x0F         | 7:0 |             | Most Significant eight bits of the seed  |

**TABLE 3-4: CLASSIC KEELoQ® TECHNOLOGY SERIAL NUMBER CONFIGURATION REGISTERS**

| Byte Address | Bit | Description   | Values                                            |
|--------------|-----|---------------|---------------------------------------------------|
| 0x10         | 7:0 | Serial Number | Least Significant eight bits of the serial number |
| 0x11         | 7:0 |               | Byte 1 of the serial number                       |
| 0x12         | 7:0 |               | Byte 2 of the serial number                       |
| 0x13         | 3:0 |               | Most Significant four bits of the serial number   |
|              | 7:4 | Reserved      | Maintain as '0000'                                |

**TABLE 3-5: CLASSIC KEELoQ® TECHNOLOGY DISC CONFIGURATION REGISTERS**

| Byte Address | Bit | Description | Values                                     |
|--------------|-----|-------------|--------------------------------------------|
| 0x14         | 7:0 | DISC Value  | Least Significant eight bits of DISC value |
| 0x15         | 1:0 |             | Most Significant two bits of DISC value    |
|              | 7:2 | Reserved    | Maintain as '000000'                       |

**TABLE 3-6: CLASSIC KEELoQ® TECHNOLOGY ENCODER CONFIGURATION REGISTERS**

| Byte Address | Bit | Description                             | Values                             |
|--------------|-----|-----------------------------------------|------------------------------------|
| 0x16         | 7:6 | Seed Option                             | 00 = No seed                       |
|              |     |                                         | 01 = Limited and immediate         |
|              |     |                                         | 10 = Permanent and delayed         |
|              |     |                                         | 11 = Permanent and immediate       |
|              | 5:2 | Reserved                                | Leave '0000'                       |
|              | 1:0 | Time Element Clock Prescaler            | 00 = 1:1                           |
|              |     |                                         | 01 = 1:4                           |
|              |     |                                         | 10 = 1:16                          |
|              |     |                                         | 11 = 1:64                          |
| 0x17         | 7   | Reserved                                | Leave '0'                          |
|              | 6:5 | Blank Alternate Code Word Configuration | 00 = All words transmitted         |
|              |     |                                         | 01 = One in two words transmitted  |
|              |     |                                         | 10 = One in four words transmitted |
|              |     |                                         | 11 = Reserved; illegal value       |
|              | 4:1 | Reserved                                | —                                  |
|              | 0   | Line Encoding                           | 0 = PWM                            |
|              |     |                                         | 1 = Manchester                     |

**TABLE 3-7: CLASSIC KEELoQ® TECHNOLOGY TRANSMITTER CONFIGURATION REGISTERS**

| Byte Address | Bit | Description         | Values                                                                                                                          |
|--------------|-----|---------------------|---------------------------------------------------------------------------------------------------------------------------------|
| 0x18         | 7:5 | Frequency Deviation | Low three bits of frequency deviation calculation (see <a href="#">Section 6.4 “Center Frequency and Frequency Deviation”</a> ) |
|              | 4   | Output Power        | 0 = 0 dBm                                                                                                                       |
|              |     |                     | 1 = +10 dBm                                                                                                                     |
|              | 3:0 | Reserved            | Reserved, maintain as '1100'                                                                                                    |
| 0x19         | 7   | Reserved            | Reserved, maintain as '0'                                                                                                       |
|              | 6   | Data Encoding       | 0 = FSK                                                                                                                         |
|              |     |                     | 1 = OOK                                                                                                                         |
|              | 5   | Band                | 0 = 310-450 MHz                                                                                                                 |
|              |     |                     | 1 = 868-870, 902-928 MHz                                                                                                        |
|              | 4:0 | Frequency Deviation | High five bits of frequency deviation calculation                                                                               |

**TABLE 3-8: CLASSIC KEELoQ® TECHNOLOGY MINIMUM AND MAXIMUM CODE WORDS COUNT CONFIGURATION REGISTERS**

| Byte Address | Bit | Description             | Values                                                                         |
|--------------|-----|-------------------------|--------------------------------------------------------------------------------|
| 0x1A         | 7:0 | Minimum Code Word Count | Integer value of the minimum number of code words sent                         |
| 0x1B         | 7:0 | Maximum Code Word Count | Least Significant eight bits of value of the maximum number of code words sent |
| 0x1C         | 7:0 |                         | Most Significant eight bits of value of the maximum number of code words sent  |

**TABLE 3-9: CLASSIC KEeloQ® TECHNOLOGY TIME ELEMENT VALUE CONFIGURATION REGISTER**

| Byte Address | Bit | Description              | Values                                      |
|--------------|-----|--------------------------|---------------------------------------------|
| 0x1D         | 7:0 | Time Element Timer Value | See <a href="#">Section 6.2 “Baud Rate”</a> |

**TABLE 3-10: ULTIMATE KEeloQ® TECHNOLOGY CRYPT KEY CONFIGURATION REGISTERS**

| Byte Address | Bit | Description | Values                                        |
|--------------|-----|-------------|-----------------------------------------------|
| 0x1E         | 7:0 | Crypt Key   | Least Significant eight bits of the crypt key |
| 0x1F         | 7:0 |             | Byte 1 of the crypt key                       |
| 0x20         | 7:0 |             | Byte 2 of the crypt key                       |
| 0x21         | 7:0 |             | Byte 3 of the crypt key                       |
| 0x22         | 7:0 |             | Byte 4 of the crypt key                       |
| 0x23         | 7:0 |             | Byte 5 of the crypt key                       |
| 0x24         | 7:0 |             | Byte 6 of the crypt key                       |
| 0x25         | 7:0 |             | Byte 7 of the crypt key                       |
| 0x26         | 7:0 |             | Byte 8 of the crypt key                       |
| 0x27         | 7:0 |             | Byte 9 of the crypt key                       |
| 0x28         | 7:0 |             | Byte 10 of the crypt key                      |
| 0x29         | 7:0 |             | Byte 11 of the crypt key                      |
| 0x2A         | 7:0 |             | Byte 12 of the crypt key                      |
| 0x2B         | 7:0 |             | Byte 13 of the crypt key                      |
| 0x2C         | 7:0 |             | Byte 14 of the crypt key                      |
| 0x2D         | 7:0 |             | Most Significant eight bits of the crypt key  |

**TABLE 3-11: ULTIMATE KEeloQ® TECHNOLOGY SEED CONFIGURATION REGISTERS**

| Byte Address | Bit | Description | Values                                   |
|--------------|-----|-------------|------------------------------------------|
| 0x2E         | 7:0 | Seed        | Least Significant eight bits of the seed |
| 0x2F         | 7:0 |             | Byte 1 of the seed                       |
| 0x30         | 7:0 |             | Byte 2 of the seed                       |
| 0x31         | 7:0 |             | Byte 3 of the seed                       |
| 0x32         | 7:0 |             | Byte 4 of the seed                       |
| 0x33         | 7:0 |             | Byte 5 of the seed                       |
| 0x34         | 7:0 |             | Byte 6 of the seed                       |
| 0x35         | 7:0 |             | Byte 7 of the seed                       |
| 0x36         | 7:0 |             | Byte 8 of the seed                       |
| 0x37         | 7:0 |             | Byte 9 of the seed                       |
| 0x38         | 7:0 |             | Byte 10 of the seed                      |
| 0x39         | 7:0 |             | Byte 11 of the seed                      |
| 0x3A         | 7:0 |             | Byte 12 of the seed                      |
| 0x3B         | 7:0 |             | Byte 13 of the seed                      |
| 0x3C         | 7:0 |             | Byte 14 of the seed                      |
| 0x3D         | 7:0 |             | Most Significant eight bits of the seed  |

**TABLE 3-12: ULTIMATE KEeloQ® TECHNOLOGY SERIAL NUMBER CONFIGURATION REGISTERS**

| Byte Address | Bit | Description   | Values                                            |
|--------------|-----|---------------|---------------------------------------------------|
| 0x3E         | 7:0 | Serial Number | Least Significant eight bits of the serial number |
| 0x3F         | 7:0 |               | Byte 1 of the serial number                       |
| 0x40         | 7:0 |               | Byte 2 of the serial number                       |
| 0x41         | 7:0 |               | Most Significant eight bits of the serial number  |

**TABLE 3-13: ULTIMATE KEeloQ® TECHNOLOGY AUTHORIZATION KEY CONFIGURATION REGISTERS**

| Byte Address | Bit | Description       | Values                                                |
|--------------|-----|-------------------|-------------------------------------------------------|
| 0x44         | 7:0 | Authorization Key | Least Significant eight bits of the authorization key |
| 0x45         | 7:0 |                   | Byte 1 of the authorization key                       |
| 0x46         | 7:0 |                   | Byte 2 of the authorization key                       |
| 0x47         | 7:0 |                   | Byte 3 of the authorization key                       |
| 0x48         | 7:0 |                   | Byte 4 of the authorization key                       |
| 0x49         | 7:0 |                   | Byte 5 of the authorization key                       |
| 0x4A         | 7:0 |                   | Byte 6 of the authorization key                       |
| 0x4B         | 7:0 |                   | Byte 7 of the authorization key                       |
| 0x4C         | 7:0 |                   | Byte 8 of the authorization key                       |
| 0x4D         | 7:0 |                   | Byte 9 of the authorization key                       |
| 0x4E         | 7:0 |                   | Byte 10 of the authorization key                      |
| 0x4F         | 7:0 |                   | Byte 11 of the authorization key                      |
| 0x50         | 7:0 |                   | Byte 12 of the authorization key                      |
| 0x51         | 7:0 |                   | Byte 13 of the authorization key                      |
| 0x52         | 7:0 |                   | Byte 14 of the authorization key                      |
| 0x53         | 7:0 |                   | Most Significant eight bits of the authorization key  |

**TABLE 3-14: ULTIMATE KEeloQ® TECHNOLOGY ENCODER CONFIGURATION REGISTERS**

| Byte Address | Bit | Description                  | Values                       |
|--------------|-----|------------------------------|------------------------------|
| 0x54         | 7:6 | Seed Option                  | 00 = No seed                 |
|              |     |                              | 01 = Limited and immediate   |
|              |     |                              | 10 = Permanent and delayed   |
|              |     |                              | 11 = Permanent and immediate |
|              | 5:2 | Reserved                     | Leave '0000'                 |
|              | 1:0 | Time Element Clock Prescaler | 00 = 1:1                     |
|              |     |                              | 01 = 1:4                     |
|              |     |                              | 10 = 1:16                    |
|              |     |                              | 11 = 1:64                    |

**TABLE 3-14: ULTIMATE KEELOQ® TECHNOLOGY ENCODER CONFIGURATION REGISTERS**

|      |     |                                         |                                    |
|------|-----|-----------------------------------------|------------------------------------|
| 0x55 | 7   | Reserved                                | Leave '0'                          |
|      | 6:5 | Blank Alternate Code Word Configuration | 00 = All words transmitted         |
|      |     |                                         | 01 = One in two words transmitted  |
|      |     |                                         | 10 = One in four words transmitted |
|      |     |                                         | 11 = Reserved; illegal value       |
|      | 4:1 | Reserved                                |                                    |
|      | 0   | Line Encoding                           | 0 = PWM                            |
|      |     |                                         | 1 = Manchester                     |

**TABLE 3-15: ULTIMATE KEELOQ® TECHNOLOGY TRANSMITTER CONFIGURATION REGISTERS**

| Byte Address | Bit | Description         | Values                                                                                                                          |
|--------------|-----|---------------------|---------------------------------------------------------------------------------------------------------------------------------|
| 0x56         | 7:5 | Frequency Deviation | Low three bits of frequency deviation calculation (see <a href="#">Section 6.4 “Center Frequency and Frequency Deviation”</a> ) |
|              | 4   | Output Power        | 0 = 0 dBm<br>1 = +10 dBm                                                                                                        |
|              | 3:0 | Reserved            | Reserved, maintain as '1100'                                                                                                    |
| 0x57         | 7   | Reserved            | Reserved, maintain as '0'                                                                                                       |
|              | 6   | Data Encoding       | 0 = FSK<br>1 = OOK                                                                                                              |
|              | 5   | Band                | 0 = 310-450 MHz<br>1 = 868-870, 902-928 MHz                                                                                     |
|              | 4:0 | Frequency Deviation | High five bits of frequency deviation calculation (see <a href="#">Section 6.4 “Center Frequency and Frequency Deviation”</a> ) |

**TABLE 3-16: ULTIMATE KEELOQ® TECHNOLOGY MINIMUM AND MAXIMUM CODE WORDS COUNT CONFIGURATION REGISTERS**

| Byte Address | Bit | Description             | Values                                                                         |
|--------------|-----|-------------------------|--------------------------------------------------------------------------------|
| 0x58         | 7:0 | Minimum Code Word Count | Integer value of the minimum number of code words sent                         |
| 0x59         | 7:0 | Maximum Code Word Count | Least Significant eight bits of value of the maximum number of code words sent |
| 0x5A         | 7:0 |                         | Most Significant eight bits of value of the maximum number of code words sent  |

**TABLE 3-17: ULTIMATE KEELOQ® TECHNOLOGY TIME ELEMENT VALUE CONFIGURATION REGISTER**

| Byte Address | Bit | Description              | Values                                               |
|--------------|-----|--------------------------|------------------------------------------------------|
| 0x5B         | 7:0 | Time Element Timer Value | See <a href="#">Section 5.2 “Encoder Time-Stamp”</a> |

**TABLE 3-18: ENCODER FREQUENCY CONFIGURATION REGISTERS**

| Byte Address | Bit | Description  | Values                                      |
|--------------|-----|--------------|---------------------------------------------|
| 0x5C         | 7:0 | RF Frequency | Least Significant Byte of encoder frequency |
| 0x5D         | 7:0 |              | Middle byte of encoder frequency            |
| 0x5E         | 7:0 |              | Most Significant Byte of encoder frequency  |

**TABLE 3-19: ENCODER BUTTON ASSIGNMENT CONFIGURATION REGISTERS**

| Byte Address | Bit | Description                                            | Values                                      |
|--------------|-----|--------------------------------------------------------|---------------------------------------------|
| 0x5F         | 7   | Encoder Assignment when S0, S1, S2 active; S3 inactive | 0 = Classic KEELoQ®<br>1 = Ultimate KEELoQ® |
|              | 6   | Encoder Assignment when S1, S2 active; S0, S3 inactive |                                             |
|              | 5   | Encoder Assignment when S0, S2 active; S1, S3 inactive |                                             |
|              | 4   | Encoder Assignment when S2 active; S0, S1, S3 inactive |                                             |
|              | 3   | Encoder Assignment when S0, S1 active; S2, S3 inactive |                                             |
|              | 2   | Encoder Assignment when S1 active; S0, S2, S3 inactive |                                             |
|              | 1   | Encoder Assignment when S0 active; S1, S2, S3 inactive |                                             |
|              | 0   | Reserved                                               |                                             |
| 0x60         | 7   | Encoder Assignment when S0, S1, S2, S3 active          |                                             |
|              | 6   | Encoder Assignment when S1, S2, S3 active; S0 inactive |                                             |
|              | 5   | Encoder Assignment when S0, S2, S3 active; S1 inactive |                                             |
|              | 4   | Encoder Assignment when S2, S3 active; S0, S1 inactive |                                             |
|              | 3   | Encoder Assignment when S0, S1, S3 active; S2 inactive |                                             |
|              | 2   | Encoder Assignment when S1, S3 active; S0, S2 inactive |                                             |
|              | 1   | Encoder Assignment when S0, S3 active; S1, S2 inactive |                                             |
|              | 0   | Encoder Assignment when S3 active; S0, S1, S2 inactive |                                             |

**TABLE 3-20: SEED BUTTON ASSIGNMENT CONFIGURATION REGISTERS**

| Byte Address | Bit | Description                                         | Values                                            |
|--------------|-----|-----------------------------------------------------|---------------------------------------------------|
| 0x61         | 7   | Seed Assignment when S0, S1, S2 active; S3 inactive | 0 = Typical transmission<br>1 = Seed transmission |
|              | 6   | Seed Assignment when S1, S2 active; S0, S3 inactive |                                                   |
|              | 5   | Seed Assignment when S0, S2 active; S1, S3 inactive |                                                   |
|              | 4   | Seed Assignment when S2 active; S0, S1, S3 inactive |                                                   |
|              | 3   | Seed Assignment when S0, S1 active; S2, S3 inactive |                                                   |
|              | 2   | Seed Assignment when S1 active; S0, S2, S3 inactive |                                                   |
|              | 1   | Seed Assignment when S0 active; S1, S2, S3 inactive |                                                   |
|              | 0   | Reserved                                            |                                                   |
| 0x62         | 7   | Seed Assignment when S0, S1, S2, S3 active          |                                                   |
|              | 6   | Seed Assignment when S1, S2, S3 active; S0 inactive |                                                   |
|              | 5   | Seed Assignment when S0, S2, S3 active; S1 inactive |                                                   |
|              | 4   | Seed Assignment when S2, S3 active; S0, S1 inactive |                                                   |
|              | 3   | Seed Assignment when S0, S1, S3 active; S2 inactive |                                                   |
|              | 2   | Seed Assignment when S1, S3 active; S0, S2 inactive |                                                   |
|              | 1   | Seed Assignment when S0, S3 active; S1, S2 inactive |                                                   |
|              | 0   | Seed Assignment when S3 active; S0, S1, S2 inactive |                                                   |

**TABLE 3-21: ULTIMATE KEELOQ® TECHNOLOGY SYNCHRONIZATION COUNTER INITIAL VALUE REGISTERS**

| Byte Address | Bit | Description                                   | Values                                                         |
|--------------|-----|-----------------------------------------------|----------------------------------------------------------------|
| 0x63         | 7:0 | Synchronization Counter Value, Primary Copy   | Least Significant Byte of counter value                        |
| 0x64         | 7:0 |                                               | Middle byte of counter value                                   |
| 0x65         | 7:0 |                                               | Most Significant Byte of counter value                         |
| 0x66         | 7:0 | Synchronization Counter CRC                   | See <a href="#">Section 3.1 “Counter and Timer Protection”</a> |
| 0x72         | 7:0 | Synchronization Counter Value, Secondary Copy | Least Significant Byte of counter value                        |
| 0x73         | 7:0 |                                               | Middle byte of counter value                                   |
| 0x74         | 7:0 |                                               | Most Significant Byte of counter value                         |

**TABLE 3-22: CLASSIC KEELOQ® TECHNOLOGY SYNCHRONIZATION COUNTER INITIAL VALUE REGISTERS**

| Byte Address | Bit | Description                                   | Values                                                         |
|--------------|-----|-----------------------------------------------|----------------------------------------------------------------|
| 0x67         | 7:0 | Synchronization Counter Value, Primary Copy   | Least Significant Byte of counter value                        |
| 0x68         | 7:0 |                                               | Most Significant Byte of counter value                         |
| 0x69         | 7:0 | Synchronization Counter CRC                   | See <a href="#">Section 3.1 “Counter and Timer Protection”</a> |
| 0x76         | 7:0 | Synchronization Counter Value, Secondary Copy | Least Significant Byte of counter value                        |
| 0x77         | 7:0 |                                               | Most Significant Byte of counter value                         |

**TABLE 3-23: ULTIMATE KEELOQ® TECHNOLOGY RESET COUNTER INITIAL VALUE REGISTERS**

| Byte Address | Bit | Description                                   | Values                                                         |
|--------------|-----|-----------------------------------------------|----------------------------------------------------------------|
| 0x6A         | 7:0 | Synchronization Counter Value, Primary Copy   | Least Significant Byte of counter value                        |
| 0x6B         | 7:0 |                                               | Most Significant Byte of counter value                         |
| 0x6C         | 7:0 | Synchronization Counter CRC                   | See <a href="#">Section 3.1 “Counter and Timer Protection”</a> |
| 0x79         | 7:0 | Synchronization Counter Value, Secondary Copy | Least Significant Byte of counter value                        |
| 0x7A         | 7:0 |                                               | Most Significant Byte of counter value                         |

**TABLE 3-24: ULTIMATE KEELOQ® TECHNOLOGY TIMER INITIAL VALUE REGISTERS**

| Byte Address | Bit | Description                 | Values                                                         |
|--------------|-----|-----------------------------|----------------------------------------------------------------|
| 0x6D         | 7:0 | Timer Value, Primary Copy   | Least Significant Byte of counter value                        |
| 0x6E         | 7:0 |                             | Byte 1 of the counter value                                    |
| 0x6F         | 7:0 |                             | Byte 2 of the counter value                                    |
| 0x70         | 7:0 |                             | Most Significant Byte of counter value                         |
| 0x71         | 7:0 | Timer CRC                   | See <a href="#">Section 3.1 “Counter and Timer Protection”</a> |
| 0x7C         | 7:0 | Timer Value, Secondary Copy | Least Significant Byte of counter value                        |
| 0x7D         | 7:0 |                             | Byte 1 of the counter value                                    |
| 0x7E         | 7:0 |                             | Byte 2 of the counter value                                    |
| 0x7F         | 7:0 |                             | Most Significant Byte of counter value                         |

## 4.0 CLASSIC KEELOQ® TECHNOLOGY OPERATION

### 4.1 Synchronization Counter

This is the 16-bit synchronization value that is used to create the hopping code for transmission. This value will be incremented after every transmission. The initial value of the synchronization counter may be set via the Synchronization Counter Initial Value registers (see [Table 3-22](#)).

### 4.2 DISC Bits

The Discrimination bits are used to validate the decrypted code word. The discrimination value is typically programmed with the ten Least Significant bits of the serial number or some other fixed value, as desired by the manufacturer.

The Discrimination bits are programmed into the Configuration registers at program-time. See [Table 3-5](#).

### 4.3 Function Code (Button Status Code)

The function code is a bitmapped representation of the state of each button on the transmitter. States are active-high.

**TABLE 4-1: CLASSIC KEELOQ® BUTTON  
CODE TRANSLATION**

| Button | Function Code |
|--------|---------------|
| S0     | xxx1          |
| S1     | xx1x          |
| S2     | x1xx          |
| S3     | 1xxx          |

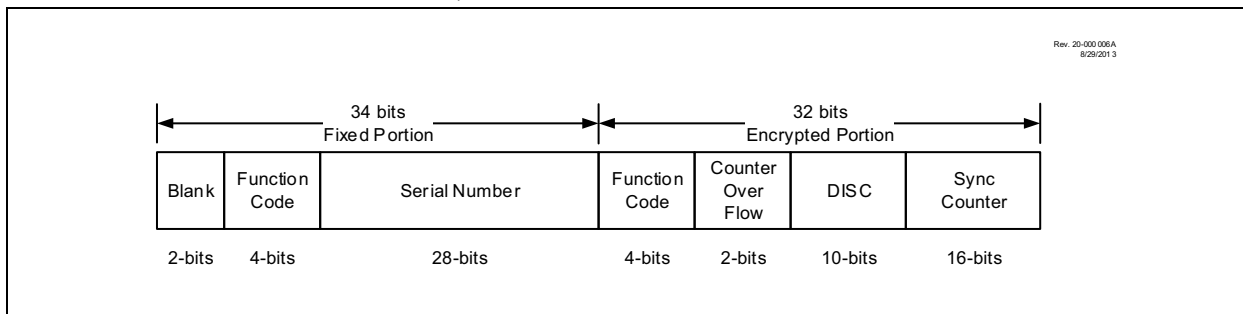
### 4.4 Serial Number

Each Classic KEELOQ encoder transmits its 28-bit serial number with each transmission. It is intended that this serial number be unique to a system. It is set in the Serial Number Configuration registers, described in [Table 3-4](#).



## 4.5 Code Word Format

**FIGURE 4-1: CLASSIC KEeloQ® CODE WORD FORMAT**



### 4.5.1 HOPPING CODE PORTION

The hopping code portion is calculated by encrypting the synchronization counter, discrimination value and function code with the encoder key. The hopping code is calculated when a button press is registered.

### 4.5.2 FIXED CODE PORTION

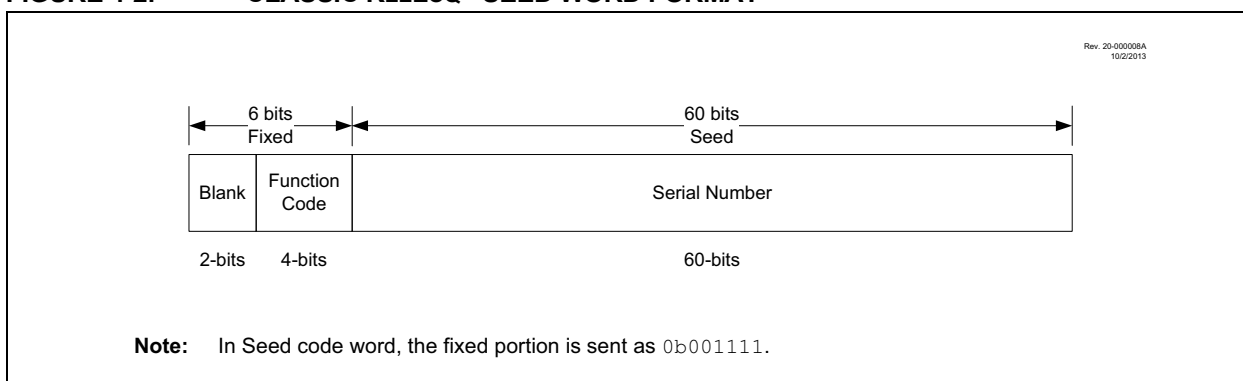
The fixed code portion consists of 28 bits of the serial number and a copy of the 4-bit function code. Two bits of constant zero are prepended to the fixed code portion.

### 4.5.3 SEED WORD FORMAT

A seed transmission transmits a code word that consists of 60 bits of fixed data that is stored in the NVM by the manufacturer. This can be used for secure learning of encoders or whenever a fixed code transmission is required. The seed code word format is shown in Figure 4-2. The function code for a seed transmission is always '1111'.

The seed word is transmitted whenever a seed-configured button combination is registered. If the *Delayed* option is enabled, the encoder will transmit 25 typical code words before transmitting seed words. If the *Limited* option is enabled, the seed word will only be transmitted if the encoder's synchronization counter is less than 256. If the synchronization counter is above this, a typical code word will be transmitted instead.

**FIGURE 4-2: CLASSIC KEeloQ® SEED WORD FORMAT**



## 5.0 ULTIMATE KEELOQ TECHNOLOGY OPERATION

### 5.1 Synchronization Counter

The synchronization counter is an always-incrementing, event-based counter. The counter is incremented whenever a new button combination is registered and a new code word is prepared.

For increased security, the synchronization counter will not overflow. The device will cease operating when the counter reaches its maximum value.

The initial value of the synchronization counter may be set via the Synchronization Counter Initial Value registers (see [Table 3-21](#)).

### 5.2 Encoder Time-Stamp

MCS3142 requires an external 31.768 kHz oscillator connected to the secondary oscillator drive pins of the internal timer. This timer is used to track the passage of time over the lifetime of the encoder. Each Ultimate KEELOQ transmission includes this time with quarter-second resolution (i.e., each count represents one quarter of a second).

The initial value of the timer may be set at programming time via the Timer Initial Value registers, described in [Table 3-24](#).

### 5.3 Function Code

The function code is a bitmapped representation of the state of each button on the transmitter. States are active-high.

**TABLE 5-1: ULTIMATE KEELOQ®  
FUNCTION CODE  
TRANSLATION**

| Button | Function Code |
|--------|---------------|
| S0     | xxx1          |
| S1     | xx1x          |
| S2     | x1xx          |
| S3     | 1xxx          |

## 5.4 Battery Level and Low Battery Flag

Each Ultimate KEELOQ transmission contains a battery level indicator byte. It includes a 7-bit digital representation of the battery level and a 1-bit low battery flag. The battery level is captured by measuring an on-board 1.024V source using the battery as reference. The low battery flag is high whenever the measured battery voltage is estimated to be below 2.5V. [Equation 5-1](#) converts the reference value into a voltage.

**EQUATION 5-1:**

$$V_{BAT} = \frac{1.024 \times 2^7}{BATT}$$

### 5.5 Button Press Timer

The button press timer is a high-resolution timer representing the duration of the current button press at the time the code word was prepared. Each count represents 50 ms of time. It resets whenever a new button combination is registered.

### 5.6 Delta Time

The delta time represents the elapsed time since the previous code word was sent. The timer increments every second.

### 5.7 Reset Counter

The Reset counter is an always-incrementing counter representing the number of Power-on Reset events experienced by the device. It is intended to be used by the receiver as an indication that the transmitter has been without power and that there will be a discrepancy in the time-stamp.

For increased security, the Reset counter will not overflow. The device will cease operating when the counter reaches its maximum value.

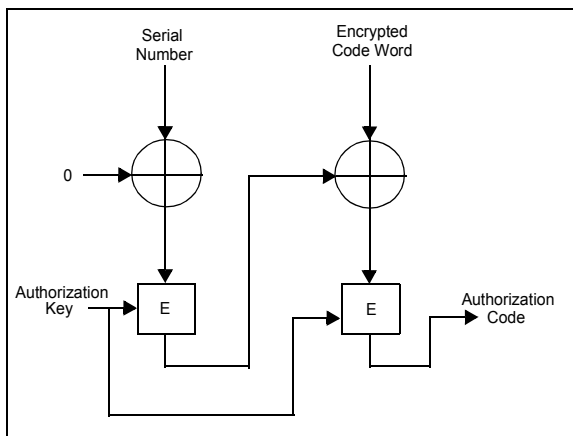
The initial value of the Reset counter may be set using the Reset Counter Configuration registers, described in [Table 3-23](#).

## 5.8 Authorization Code

The Authorization Code is a cryptographically-strong industry standard representation of the code word suitable for authentication and integrity verification. It is generated by using the on-board AES encryption algorithm in CBC-MAC mode. The calculation takes place over the entire code word, including the encrypted and unencrypted portions, using the Authorization Key as input. [Figure 5-1](#) shows a representation of how this calculation is performed. This calculation is truncated to its Least Significant 32 bits for transmission.

The Authorization Code requires a shared secret called the Authorization Key. This key is set in the Authorization Key Configuration Register, described in [Table 3-13](#).

**FIGURE 5-1: AUTHORIZATION CODE CALCULATION**



## 5.9 Serial Number

Each Ultimate KEELOQ encoder transmits its 32-bit serial number with each transmission. It is intended that this serial number be unique to a system. It is set in the Serial Number Configuration registers, described in [Table 3-12](#).

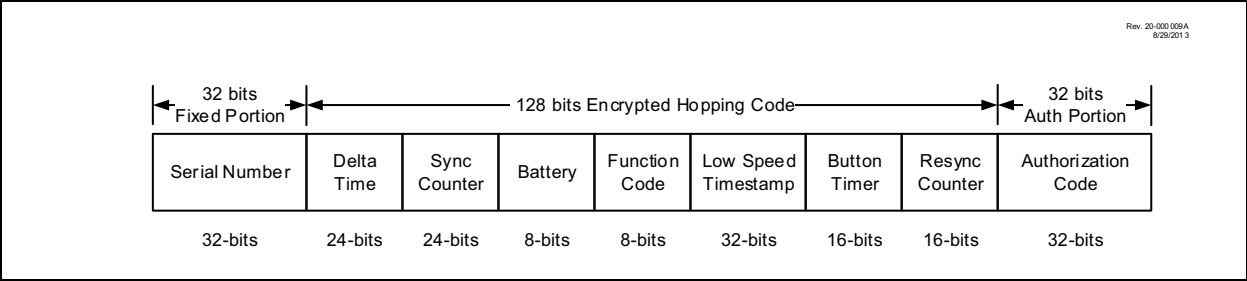
5.10 Code Word Format

The Ultimate KEELOQ technology code word is 192 bits long. It comprises three sections (see Figure 5-2):

- 32 bits of the encoder’s serial number
- 128 bits of the encrypted hopping code
- 32 bits of authorization code

These segments are described in detail in the following sections.

FIGURE 5-2: ULTIMATE KEELOQ® CODE WORD FORMAT



5.10.1 HOPPING CODE PORTION

The hopping portion of an Ultimate KEELOQ code word contains nearly all of the transmitted data. The time-stamp and Button Timer ensure that each transmission is unique.

5.10.2 FIXED CODE PORTION

The fixed, unencrypted portion of an Ultimate KEELOQ code word consists of the encoder’s serial number. Unlike Classic KEELOQ, there is no copy of the function code.

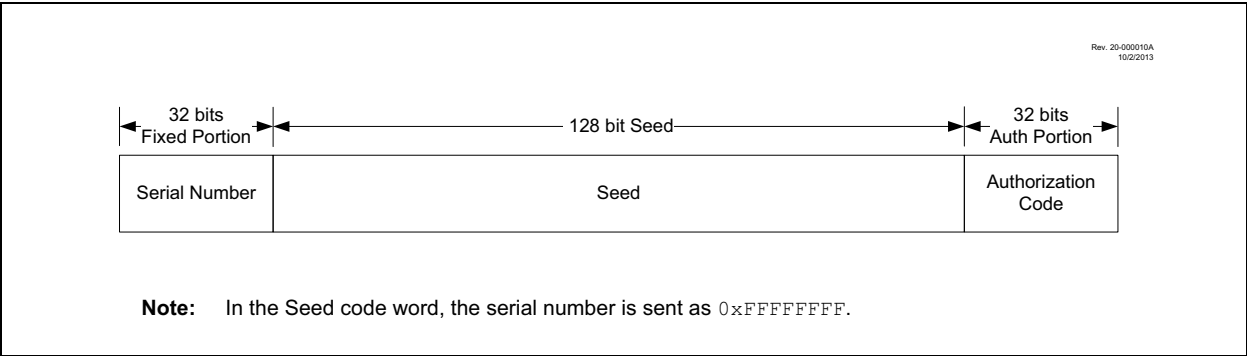
5.10.3 AUTHORIZATION CODE

The 32-bit Authorization Code is appended after the hopping portion of the code word.

5.11 Seed Word Format

The seed word is used when pairing the transmitter to a receiver using a secure learn methodology.

FIGURE 5-3: ULTIMATE KEELOQ® SEED WORD FORMAT



## 6.0 TRANSMITTER OPERATION

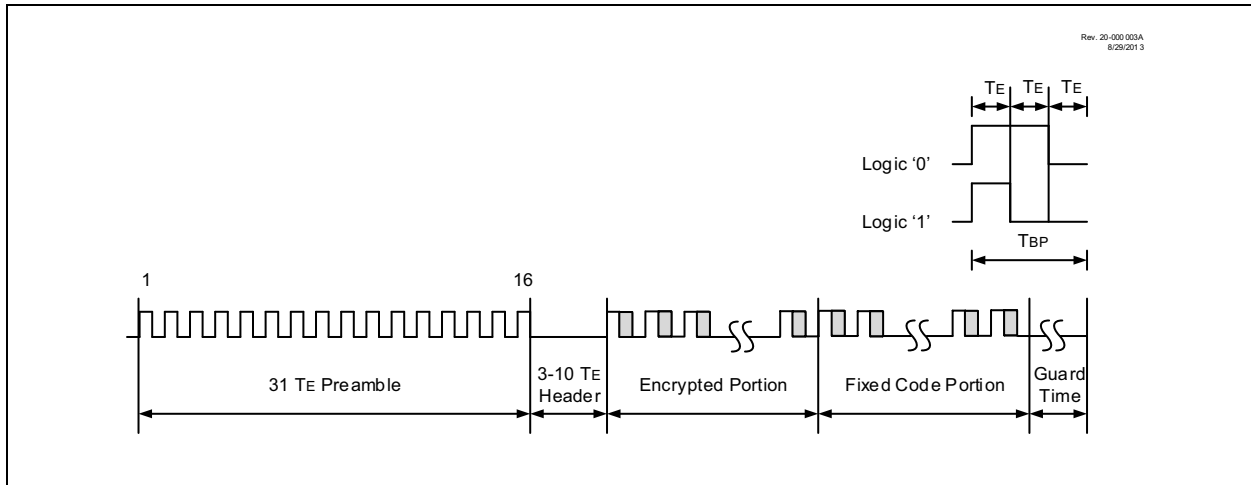
### 6.1 Data Modulation Format and Baud Rate

A transmission is made of up several code words. Each code word contains a preamble, header and data. A code word is separated from another code word by guard time.

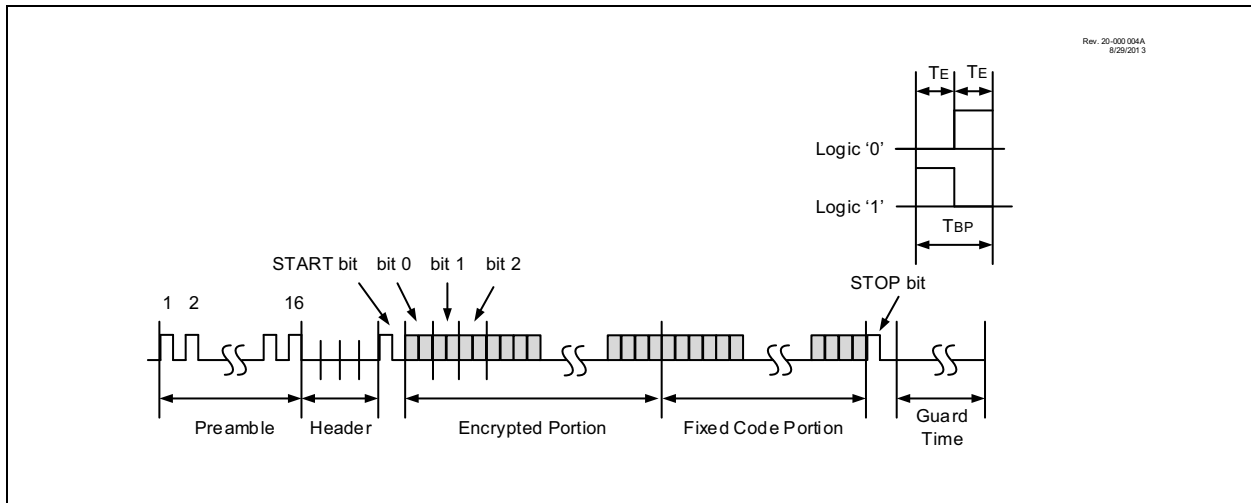
All timing specifications for the modulation formats are based on a basic Time Element, described as  $T_E$ . See [Section 6.2 “Baud Rate”](#) for details on baud rate calculation. This timing element can be set to a wide range of values. The length of the preamble, header and guard is fixed.

The data modulation format is selected for each encoder. See [Table 3-6](#) for the Classic KEELOQ encoder and [Table 3-14](#) for Ultimate KEELOQ encoder.

**FIGURE 6-1: PWM TRANSMISSION FORMAT**



**FIGURE 6-2: MANCHESTER TRANSMISSION FORMAT**



## 6.2 Baud Rate

The baud rate of an encoder's transmission is highly configurable using two configuration options:

- The Time Element Clock Prescaler
- The Time Element Clock Value

Each encoder has its own independent configuration and can therefore operate at a rate independent of the other encoder. See [Table 3-6](#) and [Table 3-9](#) for the Classic KEELOQ encoder and [Table 3-14](#) and [Table 3-17](#) for the Ultimate KEELOQ encoder.

The Time Element is calculated using the formula in [Equation 6-1](#).

### EQUATION 6-1:

$$T_E = PRE \times TIME \times \frac{4}{8 \times 10^6}$$

[Table 3-17](#) lists appropriate settings for some baud rates common to KEELOQ systems.

**TABLE 6-1: CONFIGURATION FOR COMMON BAUD RATES**

| T <sub>E</sub> (μs) | PRE  | TIME |
|---------------------|------|------|
| 100                 | 1:1  | 200  |
| 200                 | 1:4  | 100  |
| 400                 | 1:4  | 200  |
| 800                 | 1:16 | 100  |

## 6.3 Transmission Modulation Format

The RF transmission can be configured to modulate using Frequency-Shift Keying (FSK) or On-Off Keying (OOK). Each encoder may be configured independently. See [Table 3-7](#) and [Table 3-15](#) for the Classic KEELOQ and Ultimate KEELOQ encoders, respectively.

## 6.4 Center Frequency and Frequency Deviation

The RF transmitter is capable of generating many of the popular RF frequencies that are permitted within the radio regulations of the country the finished product will be sold. The RF frequency configuration is performed by selecting the frequency band, the reference crystal frequency and the frequency value to be stored in the Encoder Frequency Configuration register. If FSK modulation is used, the frequency deviation is set in the Transmitter Configuration register.

Unlike other configuration options, the two encoders of the MCS3142 device share the same frequency configuration, which is shown in Table 3-18. Frequency deviation is individually configurable. See Table 3-7 and Table 3-15 for the Classic KEELOQ and Ultimate KEELOQ encoders, respectively.

### 6.4.1 BAND SELECTION

The Band bit in the Transmitter Configuration register configures the RF transmitter for a range of frequencies for a given crystal frequency, as shown in Table 6-2. The Transmitter Configuration registers are shown in Table 3-7 for the Classic KEELOQ encoder and Table 3-15 for the Ultimate KEELOQ encoder.

Although each encoder has its own band selection configuration, the requirements of proper antenna tuning and the inability to configure the fundamental frequency per encoder will likely require that this setting be identical for both encoders.

**TABLE 6-2: FREQUENCY CALCULATION<sup>(1)</sup>**

| Reference Oscillator ( $f_{REF}$ ) | Band | Frequency Range ( $f_{RF}$ ) | $f_{RF}$ Equation                    | $f_{DEV}$ Equation                    |
|------------------------------------|------|------------------------------|--------------------------------------|---------------------------------------|
| 22 MHz                             | 0    | 310-450 MHz                  | $DF = 2^{14} \frac{f_{RF}}{f_{REF}}$ | $DA = 2^{14} \frac{f_{DEV}}{f_{REF}}$ |
| 24 MHz                             |      | 312-450 MHz                  |                                      |                                       |
| 26 MHz                             |      | 338-450 MHz                  |                                      |                                       |
|                                    | 1    | 860-928 MHz                  | $DF = 2^{13} \frac{f_{RF}}{f_{REF}}$ | $DA = 2^{13} \frac{f_{DEV}}{f_{REF}}$ |

**Note 1:**  $212992 < DF < 344064$  and  $10 \text{ kHz} \leq f_{DEV} \leq 200\text{kHz}$ .

The reference crystal frequency tolerance and frequency stability over the operating temperature range depend on the system frequency budget. Typically, the receiver crystal frequency tolerance, stability and receiver bandwidth will have the greatest influence. For OOK modulation, the transmitted RF signal should remain inside the receiver bandwidth, otherwise signal degradation will occur. For FSK modulation,  $f_{RF}$  should remain inside the receiver bandwidth and within  $0.5 f_{DEV}$ .

As a general practice, do not choose an RF transmit signal with an integer or near integer multiple of  $f_{XTAL}$ . This will result in higher noise and spurious emissions.

## 6.4.2 CRYSTAL SELECTION

Once the frequency band has been selected, the choice of crystal frequency is flexible provided the crystal meets the specifications summarized in [Table 6-3](#), the boundaries of the Encoder Frequency Configuration value are followed and the RF transmit frequency error is acceptable to the system design.

**TABLE 6-3: CRYSTAL RESONATOR SPECIFICATIONS**

| Symbol    | Description                  | Min. | Typ. | Max. | Unit     |
|-----------|------------------------------|------|------|------|----------|
| $f_{REF}$ | Crystal Frequency            | 22   | —    | 26   | MHz      |
| CL        | Load Capacitance             | —    | 15   | —    | pF       |
| ESR       | Equivalent Series Resistance | —    | —    | 100  | $\Omega$ |

## 6.4.3 FREQUENCY CALCULATION

Once the frequency band and crystal frequency are selected, the transmit frequency is calculated by setting the Encoder Frequency Configuration bits according to the formula shown in [Table 6-2](#). If the calculated value for Encoder Frequency Configuration is not an integer, there will be an associated transmit frequency error.

## 6.4.4 POWER OUTPUT

The RF output power is configurable to either +0 dBm or +10 dBm (typical). This option is configurable for each encoder. See [Table 3-7](#) for the Classic KEELOQ encoder and [Table 3-15](#) for the Ultimate KEELOQ encoder.





## 7.3 Code Word Completion

MCS3142 always ensures that a full and complete code word is transmitted even if all buttons are released before transmission is complete. Multiple code words may be transmitted after release to comply with the minimum code word configuration option.

## 7.4 Minimum and Maximum Code Word

The Minimum and Maximum Code Word feature places boundaries on the total duration of a transmission.

This feature is configured by setting the number of code words for a given encoder. The device will always transmit a complete code word. Because the code word durations are fixed and known, it is possible to convert code word counts into a duration time.

Code word duration is fixed and based on the selected bit rate, data encoding method and encoder type. As described in [Section 6.1 “Data Modulation Format and Baud Rate”](#), all timing is derived from  $T_E$ , the Time Element, which describes the duration of a single element of transmission. A Manchester-encoded signal has two  $T_E$  per bit; a PWM-encoded signal has three  $T_E$  per bit.

This feature is configured with the Minimum and Maximum Code Words Count Configuration registers (see [Table 3-8](#) for the Classic KEELOQ encoder and [Table 3-16](#) for the Ultimate KEELOQ encoder). [Table 7-2](#) defines equations to convert code word length into time.

**TABLE 7-2: TRANSMISSION DURATION EQUATIONS**

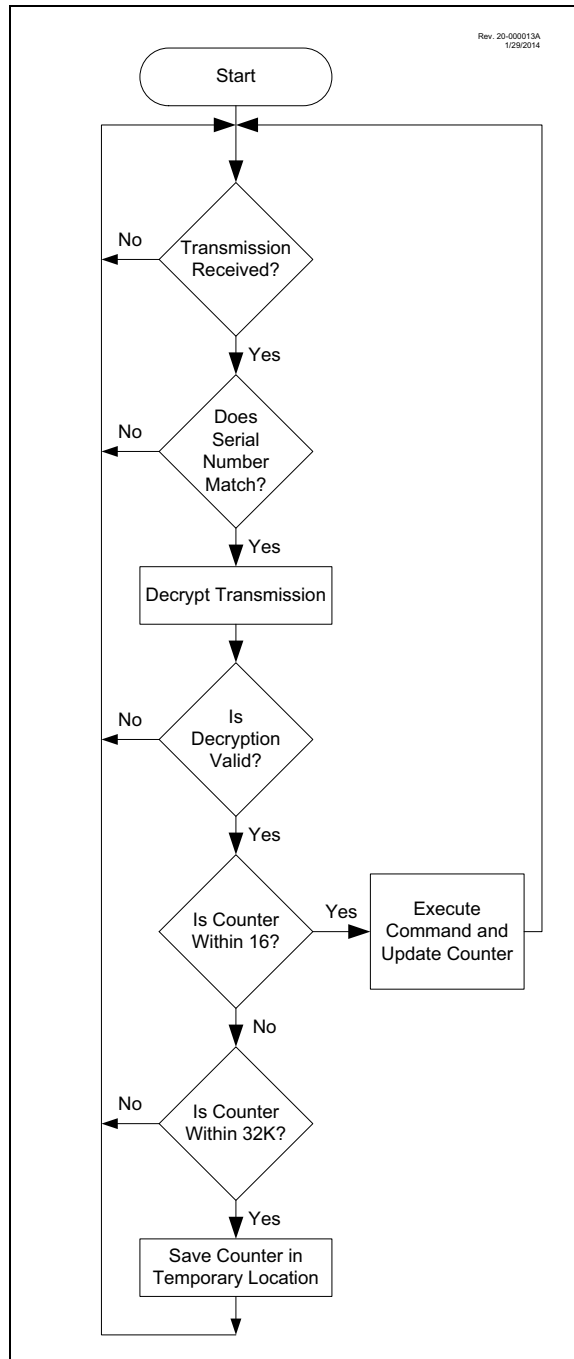
| Encoder Type             | Data Encoding | Code Word Duration                 |
|--------------------------|---------------|------------------------------------|
| Classic KEELOQ® Encoder  | Manchester    | $T_C = 187T_E + 23.979 \text{ ms}$ |
|                          | PWM           | $T_C = 201T_E + 23.979 \text{ ms}$ |
| Ultimate KEELOQ® Encoder | Manchester    | $T_C = 437T_E + 46.527 \text{ ms}$ |
|                          | PWM           | $T_C = 629T_E + 46.527 \text{ ms}$ |

## 7.5 Blank Alternate Code Word

The Blank Alternate Code Word feature may be used to reduce the average power of a transmission by transmitting only every second or every fourth code word. Enabling this option may allow the manufacturer to transmit a higher amplitude transmission as the time-averaged power is reduced. This feature is configured in the Encoder Configuration registers, see [Table 3-6](#) for the Classic KEELOQ encoder and [Table 3-14](#) for the Ultimate KEELOQ encoder.

## 8.0 INTEGRATING MCS3142 INTO A SYSTEM

**FIGURE 8-1: TYPICAL DECODER OPERATION**



### 8.1 Decoder Operation

The decoder waits until a transmission is received. The received serial number is compared to the EEPROM table of learned transmitters to first determine if this transmitter's use is allowed in the system. If from a paired transmitter, the transmission is decrypted using the stored crypt key and authenticated via the Discrimination bits for appropriate crypt key usage. If the decryption is valid, the synchronization value is evaluated (see [Figure 8-1](#)).

### 8.2 Synchronization with a Decoder

**Note:** The synchronization method described in this section is an exemplar method. It may be altered to fit the needs and capabilities of a particular system.

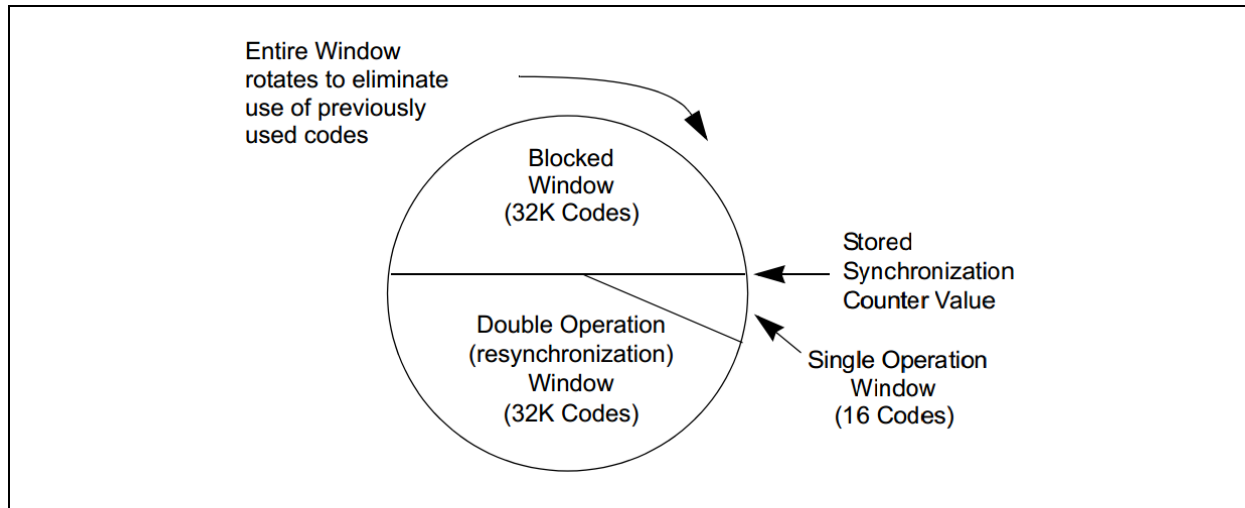
The KEELOQ technology includes a sophisticated synchronization technique that does not require the calculation and storage of future codes. The technique securely blocks invalid transmission while providing transparent resynchronization to transmitters inadvertently activated away from the receiver.

[Figure 8-2](#) shows a three-partition, rotating Synchronization window. The size of each window is optional but the technique is fundamental. Each time a transmission is authenticated, the intended function is executed and the transmission's synchronization counter value is stored in EEPROM. From the currently stored counter value there is an initial Single Operation Forward window of 16 codes. If the difference between a received synchronization counter and the last stored counter is within 16, the intended function will be executed on a single button press and the new synchronization counter will be stored. Storing the new synchronization counter value effectively rotates the entire Synchronization window.

A Double Operation (Resynchronization) window further exists from the Single Operation window up to 32K code forward of the currently stored counter value. It is referred to as Double Operation because a transmission with a synchronization counter in this window will require an additional, sequential counter transmission prior to executing the intended function. Upon receiving the sequential transmission the decoder executes the intended function and stores the synchronization counter value. This resynchronization occurs transparently to the user, as it is human nature to press the button a second time if the first was unsuccessful.

The third window is a Blocked window ranging from the Double Operation window to the currently stored synchronization counter value. Any transmission with synchronization counter value within this window will be ignored. This window excludes previously used code-grabbed transmissions from accessing the system.

**FIGURE 8-2: SYNCHRONIZATION WINDOW**



## 8.3 Security Considerations

The strength of this security is based on keeping a secret inside the transmitter that can be verified by encrypted transmissions to a trained receiver. The transmitter's secret is the manufacturer's key, not the encryption algorithm. If that key is compromised, then a smart transceiver can capture any serial number, create a valid code word and trick all receivers trained with that serial number. The key cannot be read from the EEPROM without costly die probing, but it can be calculated by brute force decryption attacks on transmitted code words. The cost for these attacks should exceed what the manufacturer would want to protect.

To protect the security of other receivers with the same manufacturer's code, the manufacturer should use the random seed for secure learn. It is a second secret that is unique for each transmitter. Its transmission on a special button press combination can be disabled if the receiver has another way to find it, or limited to the first 127 transmissions for the receiver to learn it. This way, it is very unlikely to ever be captured. If a manufacturer's key is compromised, clone transmitters can be created, but without the unique seed, they have to be relearned by the receiver. In the same way, if the transmissions are decrypted by brute force on a computer, the random seed hides the manufacturer's key and prevents more than one transmitter from being compromised.

The length of the code word at these baud rates make brute force attacks that guess the hopping code take years. To make the receiver less susceptible to this attack, it should test *all* bits in the decrypted code for the correct value, not just the low counter bits and function code.

The main benefit of hopping codes is to prevent the retransmission of captured code words. This works very well for code words which the receiver decodes. Its weakness is that, if a code is captured when the receiver misses it, the code may trick the receiver once if it is used before the next valid transmission. The receiver should increment the counter on questionable code word receptions. The transmitter should use separate buttons for lock and unlock functions. A different method would be to require two different buttons in sequence to gain access.

There are more ways to make KEELOQ systems more secure, but they all have trade-offs. The user should find a balance between security, design effort and usability, particularly in failure modes. For example, if a button sticks or kids play with it, the counter should not advance into the Blocked Code window, rendering the transmitter useless or requiring retraining.

## 9.0 ELECTRICAL SPECIFICATIONS

### 9.1 Absolute Maximum Ratings<sup>(†)</sup>

|                                      |                       |
|--------------------------------------|-----------------------|
| Ambient temperature under bias ..... | -40°C to +85°C        |
| Storage temperature .....            | -55°C to +150°C       |
| Voltage on pins with respect to Vss  |                       |
| on VDD pin .....                     | -0.3V to +4V          |
| on all other pins .....              | -0.3V to (VDD + 0.3V) |
| Maximum current                      |                       |
| on any output pin .....              | ±25 mA                |

† NOTICE: Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure above maximum rating conditions for extended periods may affect device reliability.

### 9.2 Standard Operating Conditions

The standard operating conditions for any device are defined as:

Operating Voltage:  $V_{DDMIN} \leq V_{DD} \leq V_{DDMAX}$

Operating Temperature:  $T_{A\_MIN} \leq T_A \leq T_{A\_MAX}$

#### VDD — Operating Supply Voltage

|              |       |
|--------------|-------|
| VDDMIN ..... | +1.8V |
| VDDMAX ..... | +3.6V |

#### TA — Operating Ambient Temperature Range

|              |       |
|--------------|-------|
| TA_MIN ..... | -40°C |
| TA_MAX ..... | +85°C |

#### IDD — Supply Current

|                                                        |          |
|--------------------------------------------------------|----------|
| At 315 MHz, +10 dBm, FSK, typical <sup>(1)</sup> ..... | +15 mA   |
| At 315 MHz, +10 dBm, OOK, typical <sup>(1)</sup> ..... | +11 mA   |
| At 315 MHz, +0 dBm, FSK, typical <sup>(1)</sup> .....  | +9 mA    |
| At 915 MHz, +10 dBm, FSK, typical <sup>(1)</sup> ..... | +17.5 mA |
| At 915 MHz, +0 dBm, FSK, typical <sup>(1)</sup> .....  | +10.5 mA |

#### IPD — Standby Current

|                                         |              |
|-----------------------------------------|--------------|
| VDD = 3 V, typical <sup>(1)</sup> ..... | +2.3 $\mu$ A |
| VDD = 3 V, maximum .....                | +4 $\mu$ A   |

V<sub>IH</sub> — Input High Voltage, minimum ..... 0.25 V<sub>DD</sub> + 0.8V

V<sub>IL</sub> — Input Low Voltage, maximum ..... 0.15 V<sub>DD</sub>

#### V<sub>OH</sub> — Output High Voltage

I<sub>OH</sub> = 3 mA, V<sub>DD</sub> = 3.3V, minimum ..... V<sub>DD</sub> – 0.7V

#### V<sub>OL</sub> — Output Low Voltage

I<sub>OL</sub> = 6 mA, V<sub>DD</sub> = 3.3V, maximum ..... +0.6V

I<sub>LED</sub> — LED Sink Current, maximum ..... +25 mA

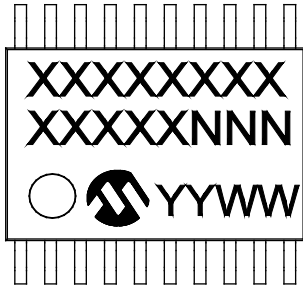
**Note 1:** Typical values are at 25°C.

# MCS3142

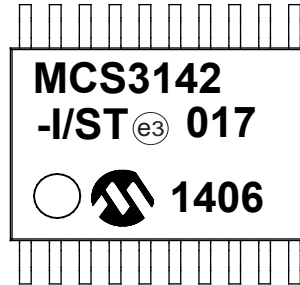
## 10.0 PACKAGING INFORMATION

### 10.1 Package Marking Information

20-Lead TSSOP



Example



|                |        |                                                                                                                  |
|----------------|--------|------------------------------------------------------------------------------------------------------------------|
| <b>Legend:</b> | XX...X | Customer-specific information                                                                                    |
|                | Y      | Year code (last digit of calendar year)                                                                          |
|                | YY     | Year code (last 2 digits of calendar year)                                                                       |
|                | WW     | Week code (week of January 1 is week '01')                                                                       |
|                | NNN    | Alphanumeric traceability code                                                                                   |
|                | (e3)   | Pb-free JEDEC® designator for Matte Tin (Sn)                                                                     |
|                | *      | This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package. |

**Note:** In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

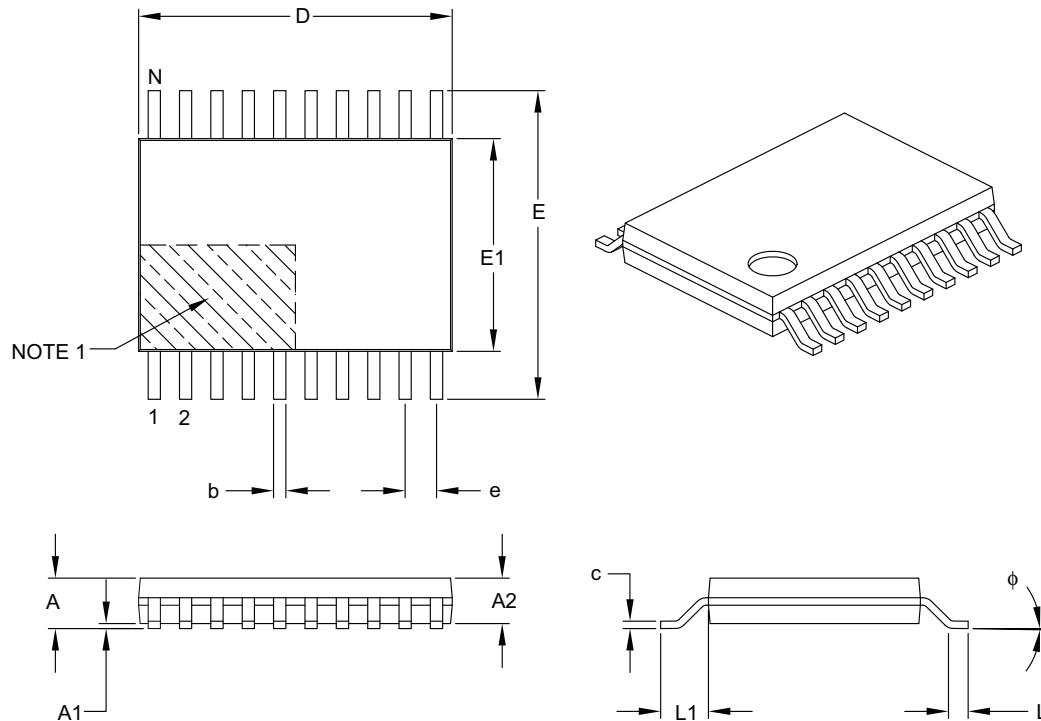
- \* Standard PIC® device marking consists of Microchip part number, year code, week code, and traceability code. For PIC device marking beyond this, certain price adders apply. Please check with your Microchip Sales Office. For QTP devices, any special marking adders are included in QTP price.

## 10.2 Package Details

The following sections give the technical details of the packages.

### 20-Lead Plastic Thin Shrink Small Outline (ST) – 4.4 mm Body [TSSOP]

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



| Units                    |    | MILLIMETERS |      |      |
|--------------------------|----|-------------|------|------|
| Dimension Limits         |    | MIN         | NOM  | MAX  |
| Number of Pins           | N  | 20          |      |      |
| Pitch                    | e  | 0.65 BSC    |      |      |
| Overall Height           | A  | –           | –    | 1.20 |
| Molded Package Thickness | A2 | 0.80        | 1.00 | 1.05 |
| Standoff                 | A1 | 0.05        | –    | 0.15 |
| Overall Width            | E  | 6.40 BSC    |      |      |
| Molded Package Width     | E1 | 4.30        | 4.40 | 4.50 |
| Molded Package Length    | D  | 6.40        | 6.50 | 6.60 |
| Foot Length              | L  | 0.45        | 0.60 | 0.75 |
| Footprint                | L1 | 1.00 REF    |      |      |
| Foot Angle               | φ  | 0°          | –    | 8°   |
| Lead Thickness           | c  | 0.09        | –    | 0.20 |
| Lead Width               | b  | 0.19        | –    | 0.30 |

**Notes:**

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15 mm per side.
- Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

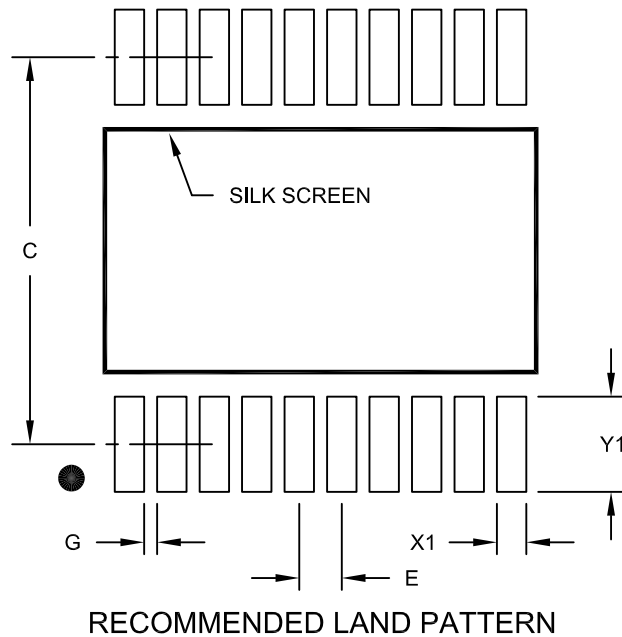
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-088B

# MCS3142

## 20-Lead Plastic Thin Shrink Small Outline (ST) - 4.4 mm Body [TSSOP]

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



| Units                    |    | MILLIMETERS |      |      |
|--------------------------|----|-------------|------|------|
| Dimension Limits         |    | MIN         | NOM  | MAX  |
| Contact Pitch            | E  | 0.65 BSC    |      |      |
| Contact Pad Spacing      | C  |             | 5.90 |      |
| Contact Pad Width (X20)  | X1 |             |      | 0.45 |
| Contact Pad Length (X20) | Y1 |             |      | 1.45 |
| Distance Between Pads    | G  | 0.20        |      |      |

**Notes:**

1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2088A



## **APPENDIX A: DATA SHEET REVISION HISTORY**

### **Revision A (03/2014)**

Initial release of the data sheet.

## THE MICROCHIP WEB SITE

Microchip provides online support via our WWW site at [www.microchip.com](http://www.microchip.com). This web site is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the web site contains the following information:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQ), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

## CUSTOMER CHANGE NOTIFICATION SERVICE

Microchip's customer notification service helps keep customers current on Microchip products. Subscribers will receive e-mail notification whenever there are changes, updates, revisions or errata related to a specified product family or development tool of interest.

To register, access the Microchip web site at [www.microchip.com](http://www.microchip.com). Under "Support", click on "Customer Change Notification" and follow the registration instructions.

## CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or Field Application Engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

**Technical support is available through the web site at:** <http://microchip.com/support>.

## PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

| <u>PART NO.</u>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <u>[X]<sup>(1)</sup></u> | - | <u>X</u>          | <u>/XX</u> | <u>XXX</u> |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|---|-------------------|------------|------------|
| Device                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Tape and Reel Option     |   | Temperature Range | Package    | Pattern    |
| <div> <div> <b>Device:</b> MCS3142 </div> <div> <b>Tape and Reel Option:</b> Blank = Standard packaging (tube or tray)<br/>T = Tape and Reel<sup>(1)</sup> </div> <div> <b>Temperature Range:</b> I = -40°C to +85°C (Industrial) </div> <div> <b>Package:<sup>(2)</sup></b> ST = TSSOP </div> <div> <b>Pattern:</b> QTP, SQTP, Code or Special Requirements (blank otherwise) </div> </div>                                                                                                                 |                          |   |                   |            |            |
| <b>Examples:</b><br>a) MCS3142 - I/ST<br>Industrial temperature, TSSOP package                                                                                                                                                                                                                                                                                                                                                                                                                               |                          |   |                   |            |            |
| <b>Note 1:</b> Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip Sales Office for package availability with the Tape and Reel option.<br><br><b>2:</b> For other small form-factor package availability and marking information, please visit <a href="http://www.microchip.com/packaging">www.microchip.com/packaging</a> or contact your local sales office. |                          |   |                   |            |            |

---

---

**Note the following details of the code protection feature on Microchip devices:**

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights.

#### **Trademarks**

The Microchip name and logo, the Microchip logo, dsPIC, FlashFlex, KEELQ, KEELQ logo, MPLAB, PIC, PICmicro, PICSTART, PIC<sup>32</sup> logo, rPIC, SST, SST Logo, SuperFlash and UNI/O are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

FilterLab, Hampshire, HI-TECH C, Linear Active Thermistor, MTP, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Inc. in other countries.

Analog-for-the-Digital Age, Application Maestro, BodyCom, chipKIT, chipKIT logo, CodeGuard, dsPICDEM, dsPICDEM.net, dsPICworks, dsSPEAK, ECAN, ECONOMONITOR, FanSense, HI-TIDE, In-Circuit Serial Programming, ICSP, Mindi, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, mTouch, Omniclient Code Generation, PICC, PICC-18, PICDEM, PICDEM.net, PICkit, PICTail, REAL ICE, rLAB, Select Mode, SQI, Serial Quad I/O, Total Endurance, TSHARC, UniWinDriver, WiperLock, ZENA and Z-Scale are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

GestIC and ULPP are registered trademarks of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

© 2013, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

 Printed on recycled paper.

ISBN: 978-1-63276-006-7

**QUALITY MANAGEMENT SYSTEM**  
**CERTIFIED BY DNV**  
**= ISO/TS 16949 =**

*Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.*

## Worldwide Sales and Service

### AMERICAS

**Corporate Office**  
2355 West Chandler Blvd.  
Chandler, AZ 85224-6199  
Tel: 480-792-7200  
Fax: 480-792-7277  
Technical Support:  
<http://www.microchip.com/support>  
Web Address:  
[www.microchip.com](http://www.microchip.com)

**Atlanta**  
Duluth, GA  
Tel: 678-957-9614  
Fax: 678-957-1455

**Austin, TX**  
Tel: 512-257-3370

**Boston**  
Westborough, MA  
Tel: 774-760-0087  
Fax: 774-760-0088

**Chicago**  
Itasca, IL  
Tel: 630-285-0071  
Fax: 630-285-0075

**Cleveland**  
Independence, OH  
Tel: 216-447-0464  
Fax: 216-447-0643

**Dallas**  
Addison, TX  
Tel: 972-818-7423  
Fax: 972-818-2924

**Detroit**  
Novi, MI  
Tel: 248-848-4000

**Houston, TX**  
Tel: 281-894-5983

**Indianapolis**  
Noblesville, IN  
Tel: 317-773-8323  
Fax: 317-773-5453

**Los Angeles**  
Mission Viejo, CA  
Tel: 949-462-9523  
Fax: 949-462-9608

**New York, NY**  
Tel: 631-435-6000

**San Jose, CA**  
Tel: 408-735-9110

**Canada - Toronto**  
Tel: 905-673-0699  
Fax: 905-673-6509

### ASIA/PACIFIC

**Asia Pacific Office**  
Suites 3707-14, 37th Floor  
Tower 6, The Gateway  
Harbour City, Kowloon  
Hong Kong  
Tel: 852-2401-1200  
Fax: 852-2401-3431

**Australia - Sydney**  
Tel: 61-2-9868-6733  
Fax: 61-2-9868-6755

**China - Beijing**  
Tel: 86-10-8569-7000  
Fax: 86-10-8528-2104

**China - Chengdu**  
Tel: 86-28-8665-5511  
Fax: 86-28-8665-7889

**China - Chongqing**  
Tel: 86-23-8980-9588  
Fax: 86-23-8980-9500

**China - Hangzhou**  
Tel: 86-571-8792-8115  
Fax: 86-571-8792-8116

**China - Hong Kong SAR**  
Tel: 852-2943-5100  
Fax: 852-2401-3431

**China - Nanjing**  
Tel: 86-25-8473-2460  
Fax: 86-25-8473-2470

**China - Qingdao**  
Tel: 86-532-8502-7355  
Fax: 86-532-8502-7205

**China - Shanghai**  
Tel: 86-21-5407-5533  
Fax: 86-21-5407-5066

**China - Shenyang**  
Tel: 86-24-2334-2829  
Fax: 86-24-2334-2393

**China - Shenzhen**  
Tel: 86-755-8864-2200  
Fax: 86-755-8203-1760

**China - Wuhan**  
Tel: 86-27-5980-5300  
Fax: 86-27-5980-5118

**China - Xian**  
Tel: 86-29-8833-7252  
Fax: 86-29-8833-7256

**China - Xiamen**  
Tel: 86-592-2388138  
Fax: 86-592-2388130

**China - Zhuhai**  
Tel: 86-756-3210040  
Fax: 86-756-3210049

### ASIA/PACIFIC

**India - Bangalore**  
Tel: 91-80-3090-4444  
Fax: 91-80-3090-4123

**India - New Delhi**  
Tel: 91-11-4160-8631  
Fax: 91-11-4160-8632

**India - Pune**  
Tel: 91-20-3019-1500

**Japan - Osaka**  
Tel: 81-6-6152-7160  
Fax: 81-6-6152-9310

**Japan - Tokyo**  
Tel: 81-3-6880-3770  
Fax: 81-3-6880-3771

**Korea - Daegu**  
Tel: 82-53-744-4301  
Fax: 82-53-744-4302

**Korea - Seoul**  
Tel: 82-2-554-7200  
Fax: 82-2-558-5932 or  
82-2-558-5934

**Malaysia - Kuala Lumpur**  
Tel: 60-3-6201-9857  
Fax: 60-3-6201-9859

**Malaysia - Penang**  
Tel: 60-4-227-8870  
Fax: 60-4-227-4068

**Philippines - Manila**  
Tel: 63-2-634-9065  
Fax: 63-2-634-9069

**Singapore**  
Tel: 65-6334-8870  
Fax: 65-6334-8850

**Taiwan - Hsin Chu**  
Tel: 886-3-5778-366  
Fax: 886-3-5770-955

**Taiwan - Kaohsiung**  
Tel: 886-7-213-7830

**Taiwan - Taipei**  
Tel: 886-2-2508-8600  
Fax: 886-2-2508-0102

**Thailand - Bangkok**  
Tel: 66-2-694-1351  
Fax: 66-2-694-1350

### EUROPE

**Austria - Wels**  
Tel: 43-7242-2244-39  
Fax: 43-7242-2244-393

**Denmark - Copenhagen**  
Tel: 45-4450-2828  
Fax: 45-4485-2829

**France - Paris**  
Tel: 33-1-69-53-63-20  
Fax: 33-1-69-30-90-79

**Germany - Dusseldorf**  
Tel: 49-2129-3766400

**Germany - Munich**  
Tel: 49-89-627-144-0  
Fax: 49-89-627-144-44

**Germany - Pforzheim**  
Tel: 49-7231-424750

**Italy - Milan**  
Tel: 39-0331-742611  
Fax: 39-0331-466781

**Italy - Venice**  
Tel: 39-049-7625286

**Netherlands - Drunen**  
Tel: 31-416-690399  
Fax: 31-416-690340

**Poland - Warsaw**  
Tel: 48-22-3325737

**Spain - Madrid**  
Tel: 34-91-708-08-90  
Fax: 34-91-708-08-91

**Sweden - Stockholm**  
Tel: 46-8-5090-4654

**UK - Wokingham**  
Tel: 44-118-921-5800  
Fax: 44-118-921-5820