HCS360

KEELOQ® Code Hopping Encoder

FEATURES

Security

- Programmable 28/32-bit serial number
- Programmable 64-bit encryption key
- Each transmission is unique
- 67-bit transmission code length
- 32-bit hopping code
- 35-bit fixed code (28/32-bit serial number, 4/0-bit function code, 1-bit status, 2-bit CRC)
- Encryption keys are read protected

Operating

- 2.0-6.6V operation
- Four button inputs
  - 15 functions available
- Selectable baud rate
- Automatic code word completion
- Battery low signal transmitted to receiver
- Nonvolatile synchronization data
- PWM and Manchester modulation

Other

- Easy-to-use programming interface
- On-chip EEPROM
- On-chip oscillator and timing components
- Button inputs have internal pull-down resistors
- Current limiting on LED output
- Minimum component count

Enhanced Features Over HCS300

- 48-bit seed vs. 32-bit seed
- 2-bit CRC for error detection
- 28/32-bit serial number select
- Two seed transmission methods
- PWM and Manchester modulation
- IR Modulation mode

Typical Applications

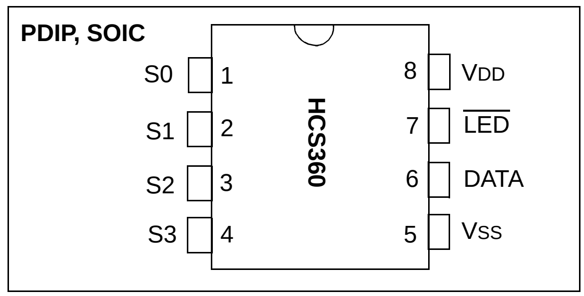
The HCS360 is ideal for Remote Keyless Entry (RKE) applications. These applications include:

- Automotive RKE systems
- Automotive alarm systems
- Automotive immobilizers
- Gate and garage door openers
- Identity tokens
- Burglar alarm systems

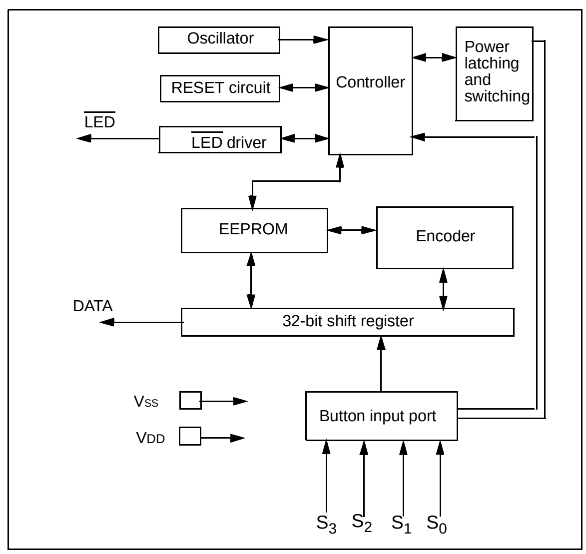
DESCRIPTION

The HCS360 is a code hopping encoder designed for secure Remote Keyless Entry (RKE) systems. The HCS360 utilizes the KEELOQ code hopping technology, which incorporates high security, a small package outline and low cost, to make this device a perfect solution for unidirectional remote keyless entry systems and access control systems.

PACKAGE TYPES



BLOCK DIAGRAM



The HCS360 combines a 32-bit hopping code generated by a nonlinear encryption algorithm, with a 28/32-bit serial number and 7/3 status bits to create a 67-bit transmission stream.

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. The HCS360 provides an easy-to-use serial interface for programming the necessary keys, system parameters and configuration data.

1.0 SYSTEM OVERVIEW

Key Terms

The following is a list of key terms used throughout this data sheet. For additional information on KEELOQ and Code Hopping, refer to Technical Brief 3 (TB003).

- **RKE** - Remote Keyless Entry
- **Button Status** - Indicates what button input(s) activated the transmission. Encompasses the 4 button status bits S3, S2, S1 and S0 (Figure 3-1).
- **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 (Figure 3-1).
- **Transmission** - A data stream consisting of repeating code words (Figure 8-1).
- **Crypt key** - A unique and secret 64-bit number used to encrypt and decrypt data. In a symmetrical block cipher such as the KEELOQ algorithm, the encryption and decryption keys are equal and will therefore be referred to generally as the crypt key.
- **Encoder** - A device that generates and encodes data.
- **Encryption Algorithm** - A recipe 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.
- **Learn** – Learning involves the receiver calculating the transmitter's appropriate crypt key, decrypting the received hopping code and storing the serial number, synchronization counter value and crypt key in EEPROM. The KEELOQ 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, common to all components of all systems by the same manufacturer, to decrypt the received code word's encrypted portion.
  - **Normal Learning**
    The receiver uses information transmitted during normal operation to derive the crypt key and decrypt the received code word's encrypted portion.
  - **Secure Learn**
    The transmitter is activated through a special button combination to transmit a stored 60-bit seed value used to generate the transmitter's crypt key. The receiver uses this seed value to derive the same crypt key and decrypt the received code word's encrypted portion.
- **Manufacturer's code** – A unique and secret 64-bit number used to generate unique encoder 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 code itself.

The HCS360 code hopping encoder is designed specifically for keyless entry systems; primarily vehicles and home garage door openers. The encoder portion of a keyless entry system is integrated into a transmitter, carried by the user and operated to gain access to a vehicle or restricted area. The HCS360 is meant to be a cost-effective yet secure solution to such systems, requiring very few external components (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.

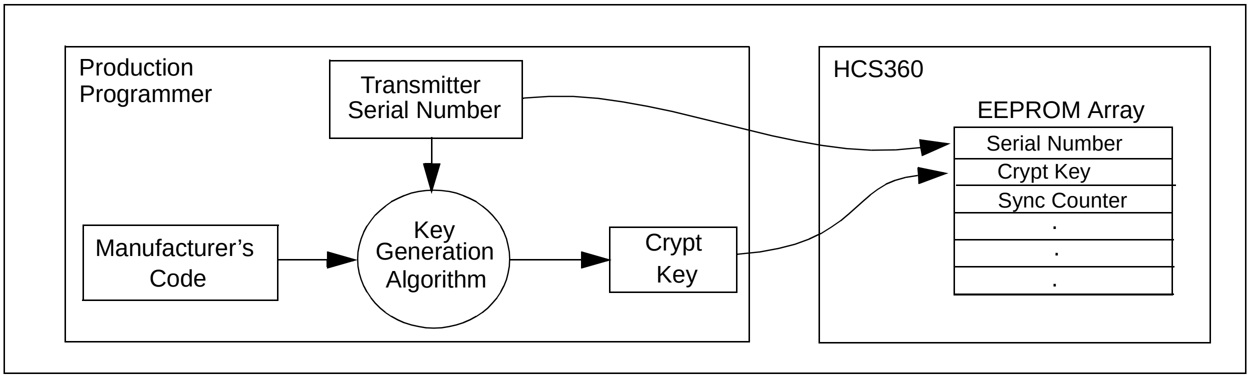
The HCS360, on the other hand, employs the KEELOQ code hopping technology coupled with a transmission length of 66 bits to virtually eliminate the use of code 'grabbing' or code 'scanning'. The high security level of the HCS360 is based on the patented KEELOQ technology. A block cipher based on a block length of 32 bits and a key length of 64 bits is used. The algorithm obscures the information in such a way that even if the transmission information (before coding) differs by only one bit from that of the previous transmission, the next coded transmission will be completely different. Statistically, if only one bit in the 32-bit string of information changes, greater than 50 percent of the coded transmission bits will change.

As indicated in the block diagram on page one, the HCS360 has a small EEPROM array which must be loaded with several parameters before use; most often programmed by the manufacturer at the time of production. The most important of these are:

- A 28-bit serial number, typically unique for every encoder
- A crypt key
- An initial 16-bit synchronization value
- A 16-bit configuration value

The crypt key generation typically inputs the transmitter serial number and 64-bit manufacturer's code into the key generation algorithm (Figure 1-1). The manufacturer's code is chosen by the system manufacturer and must be carefully controlled as it is a pivotal part of the overall system security.

FIGURE 1-1: CREATION AND STORAGE OF CRYPT KEY DURING PRODUCTION



The 16-bit synchronization counter is the basis behind the transmitted code word changing for each transmission; it increments each time a button is pressed. Due to the code hopping algorithm's complexity, each increment of the synchronization value results in greater than 50% of the bits changing in the transmitted code word.

Figure 1-2 shows how the key values in EEPROM are used in the encoder. Once the encoder detects a button press, it reads the button inputs and updates the synchronization counter. The synchronization counter and crypt key are input to the encryption algorithm and the output is 32 bits of encrypted information. This data will change with every button press, its value appearing externally to 'randomly hop around', hence it is referred to as the hopping portion of the code word. The 32-bit hopping code is combined with the button information and serial number to form the code word transmitted to the receiver. The code word format is explained in greater detail in Section 4.2.

A receiver may use any type of controller as a decoder, but it is typically a microcontroller with compatible firmware that allows the decoder to operate in conjunction with an HCS360 based transmitter. Section 7.0 provides detail on integrating the HCS360 into a system.

A transmitter must first be 'learned' by the receiver before its use is allowed in the system. Learning includes calculating the transmitter's appropriate crypt key, decrypting the received hopping code and storing the serial number, synchronization counter value and crypt key in EEPROM.

In normal operation, each received message of valid format is evaluated. The serial number is used to determine if it is from a learned transmitter. If from a learned transmitter, the message is decrypted and the synchronization counter is verified. Finally, the button status is checked to see what operation is requested. Figure 1-3 shows the relationship between some of the values stored by the receiver and the values received from the transmitter.

FIGURE 1-2: BUILDING THE TRANSMITTED CODE WORD (ENCODER)

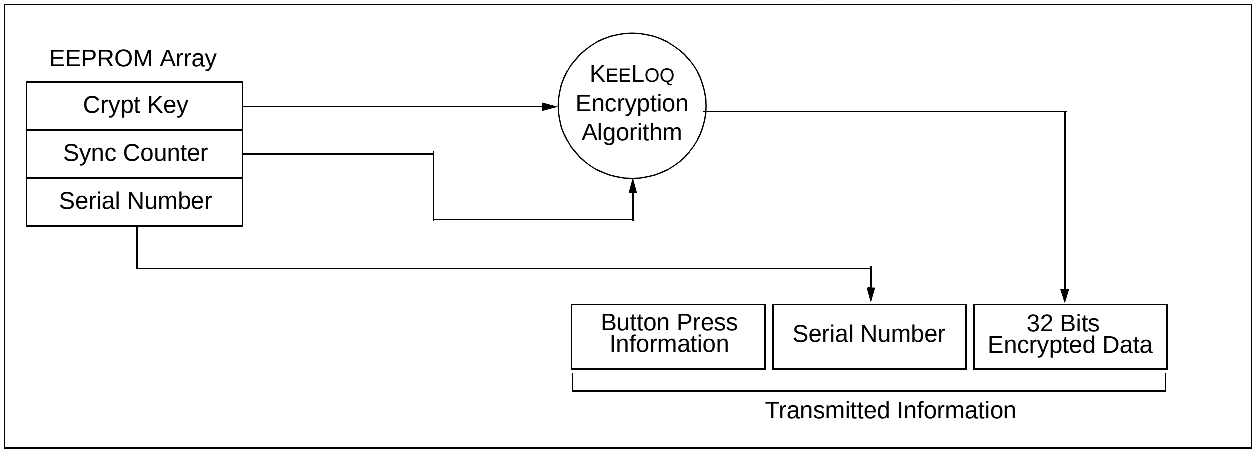
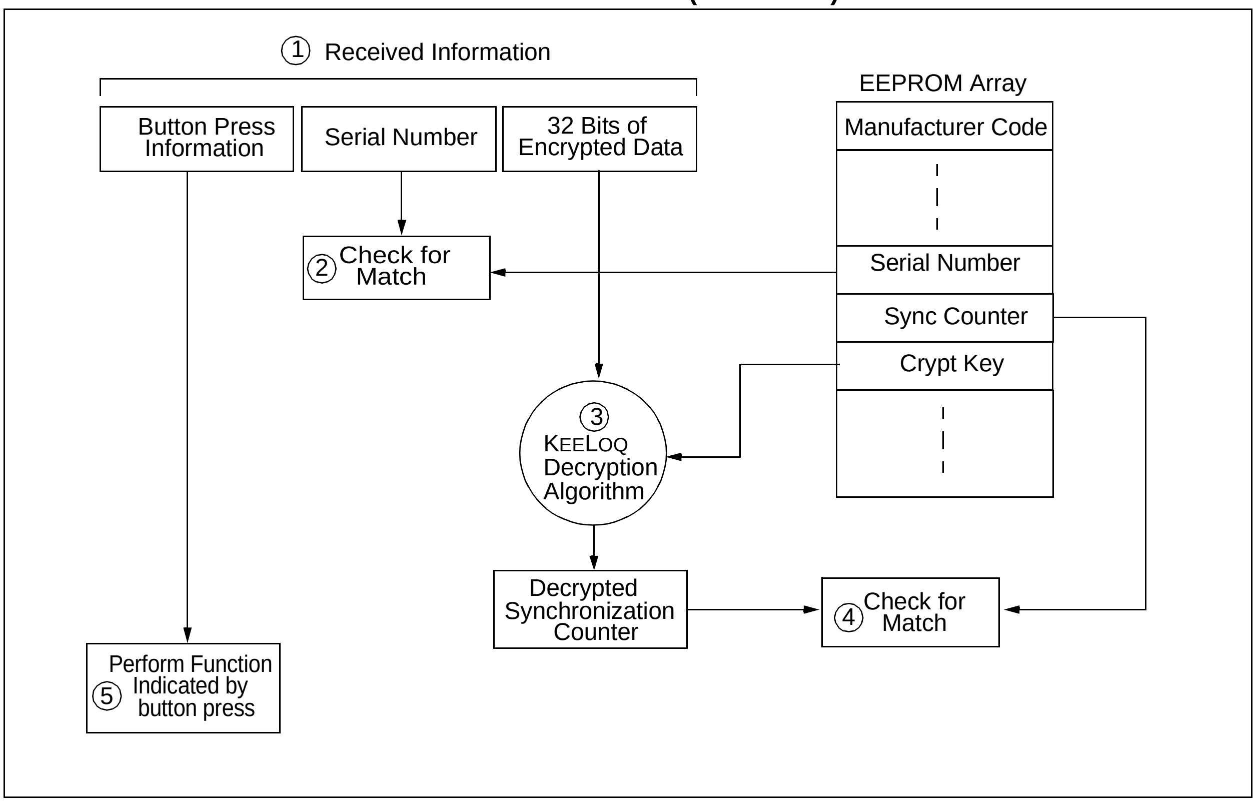


FIGURE 1-3: BASIC OPERATION OF RECEIVER (DECODER)

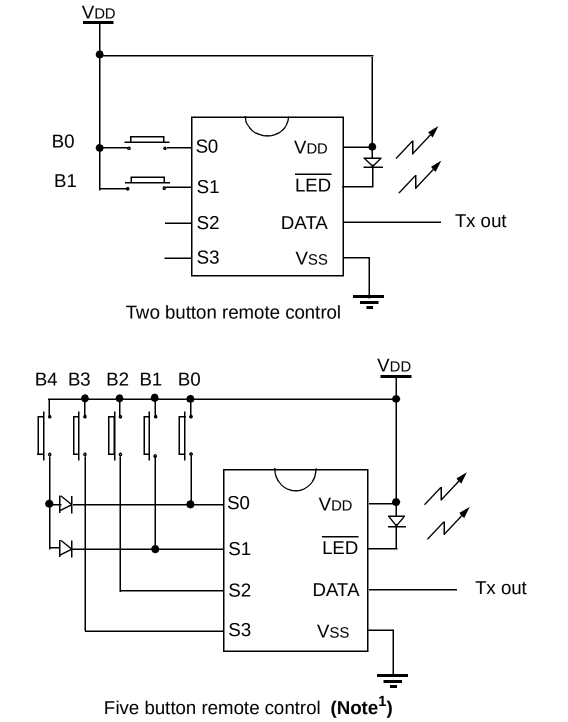


NOTE: Circled numbers indicate the order of execution.

2.0 DEVICE OPERATION

As shown in the typical application circuits (Figure 2-1), the HCS360 is a simple device to use. It requires only the addition of buttons and RF circuitry for use as the transmitter in your security application. A description of each pin is described in Table 2-1.

FIGURE 2-1: TYPICAL CIRCUITS



Note: Up to 15 functions can be implemented by pressing more than one button simultaneously or by using a suitable diode array.

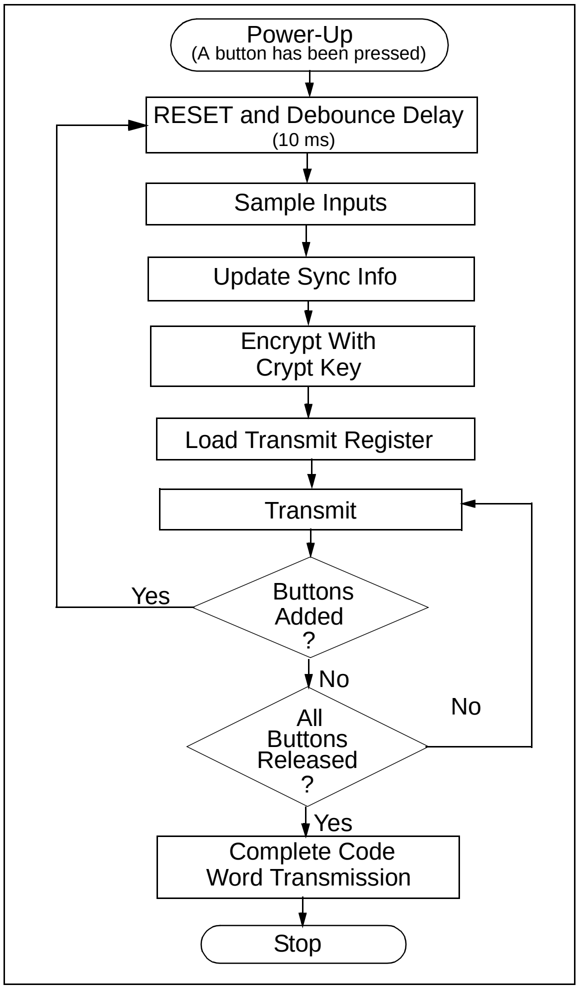
TABLE 2-1: PIN DESCRIPTIONS

Name	Pin Number	Description
S0	1	Switch input 0
S1	2	Switch input 1
S2	3	Switch input 2 / Clock pin when in Programming mode
S3	4	Switch input 3
VSS	5	Ground reference
DATA	6	Data output pin /Data I/O pin for Programming mode
$\overline{\text{LED}}$	7	Cathode connection for $\overline{\text{LED}}$
VDD	8	Positive supply voltage

The HCS360 will wake-up upon detecting a button press and delay approximately 10 ms for button debounce (Figure 2-2). The synchronization counter, discrimination value and button information will be encrypted to form the hopping code. The hopping code portion will change every transmission, even if the same button is pushed again. A code word that has been transmitted will not repeat for more than 64K transmissions. This provides more than 18 years of use before a code is repeated; based on 10 operations per day. Overflow information sent from the encoder can be used to extend the number of unique transmissions to more than 192K.

If in the transmit process it is detected that a new button(s) has been pressed, a RESET will immediately occur and the current code word will not be completed. Please note that buttons removed will not have any effect on the code word unless no buttons remain pressed; in which case the code word will be completed and the power-down will occur.

FIGURE 2-2: ENCODER OPERATION



3.0 EEPROM MEMORY ORGANIZATION

The HCS360 contains 192 bits (12 x 16-bit words) of EEPROM memory (Table 3-1). This EEPROM array is used to store the crypt key information, synchronization value, etc. Further descriptions of the memory array is given in the following sections.

TABLE 3-1: EEPROM MEMORY MAP

WORD ADDRESS	MNEMONIC	DESCRIPTION
0	KEY_0	64-bit crypt key (word 0) LSb's
1	KEY_1	64-bit crypt key (word 1)
2	KEY_2	64-bit crypt key (word 2)
3	KEY_3	64-bit crypt key (word 3) MSb's
4	SYNC_A	16-bit synch counter
5	SYNC_B/ SEED_2	16-bit synch counter B or Seed value (word 2)
6	RESERVED	Set to 0000H
7	SEED_0	Seed Value (word 0) LSb's
8	SEED_1	Seed Value (word 1) MSb's
9	SER_0	Device Serial Number (word 0) LSb's
10	SER_1	Device Serial Number (word 1) MSb's
11	CONFIG	Configuration Word

3.1 KEY_0 - KEY_3 (64-Bit Crypt Key)

The 64-bit crypt key is used to create the encrypted message transmitted to the receiver. This key is calculated and programmed during production using a key generation algorithm. The key generation algorithm may be different from the KEELOQ algorithm. Inputs to the key generation algorithm are typically the transmitter's serial number and the 64-bit manufacturer's code. While the key generation algorithm supplied from Microchip is the typical method used, a user may elect to create their own method of key generation. This may be done providing that the decoder is programmed with the same means of creating the key for decryption purposes.

3.2 SYNC_A, SYNC_B (Synchronization Counter)

This is the 16-bit synchronization value that is used to create the hopping code for transmission. This value is incremented after every transmission. Separate synchronization counters can be used to stay synchronized with different receivers.

3.3 SEED_0, SEED_1, and SEED_2 (Seed Word)

The three word (48 bits) seed code will be transmitted when seed transmission is selected. This allows the system designer to implement the Secure Learn feature or use this fixed code word as part of a different key generation/tracking process or purely as a fixed code transmission.

Note:	Since SEED2 and SYNC_B share the same memory location, Secure Learn and Independent mode transmission (including IR mode) are mutually exclusive.

3.4 SER_0, SER_1 (Encoder Serial Number)

SER_0 and SER_1 are the lower and upper words of the device serial number, respectively. There are 32 bits allocated for the Serial Number and a selectable configuration bit determines whether 32 or 28 bits will be transmitted. The serial number is meant to be unique for every transmitter.

3.5 CONFIG (Configuration Word)

The Configuration Word is a 16-bit word stored in EEPROM array that is used by the device to store information used during the encryption process, as well as the status of option configurations. Further explanations of each of the bits are described in the following sections.

TABLE 3-2: CONFIGURATION WORD.

Bit Number	Symbol	Bit Description
0	LNGRD	Long Guard Time
1	BSEL 0	Baud Rate Selection
2	BSEL 1	Baud Rate Selection
3	NU	Not Used
4	SEED	Seed Transmission enable
5	DELM	Delay mode enable
6	TIMO	Time-out enable
7	IND	Independent mode enable
8	USRA0	User bit
9	USRA1	User bit
10	USRB0	User bit
11	USRB1	User bit
12	XSER	Extended serial number enable
13	TMPSD	Temporary seed transmission enable
14	MOD	Manchester/PWM modulation selection
15	OVR	Overflow bit

3.5.1 MOD: MODULATION FORMAT

MOD selects between Manchester code modulation and PWM modulation.

If MOD = 1, Manchester modulation is selected:

If MOD = 0, PWM modulation is selected.

3.5.2 BSEL 1, 0 BAUD RATE SELECTION

BSEL 1 and BSEL 0 determine the baud rate according to Table 3-3 when PWM modulation is selected.

TABLE 3-3: BAUD RATE SELECTION

MOD	BSEL 1	BSEL 0	T_E	Unit
0	0	0	400	us
0	0	1	200	us
0	1	0	200	us
0	1	1	100	us

BSEL 1 and BSEL 0 determine the baud rate according to Table 3-4 when Manchester modulation is selected.

TABLE 3-4: BAUD RATE SELECTION

MOD	BSEL 1	BSEL 0	T_E	Unit
1	0	0	800	us
1	0	1	400	us
1	1	0	400	us
1	1	1	200	us

3.5.3 OVR: OVERFLOW

The overflow bit is used to extend the number of possible synchronization values. The synchronization counter is 16 bits in length, yielding 65,536 values before the cycle repeats. Under typical use of 10 operations a day, this will provide nearly 18 years of use before a repeated value will be used. Should the system designer conclude that is not adequate, then the overflow bit can be utilized to extend the number of unique values. This can be done by programming OVR to 1 at the time of production. The encoder will automatically clear OVR the first time that the transmitted synchronization value wraps from 0xFFFF to 0x0000. Once cleared, OVR cannot be set again, thereby creating a permanent record of the counter overflow. This prevents fast cycling of 64K counter. If the decoder system is programmed to track the overflow bits, then the effective number of unique synchronization values can be extended to 128K. If programmed to zero, the system will be compatible with old encoder devices.

3.5.4 LNGRD: LONG GUARD TIME

LNGRD = 1 selects the encoder to extend the guard time between code words adding ≈50 ms. This can be used to reduce the average power transmitted over a 100 ms window and thereby transmit a higher peak power.

3.5.5 XSER: EXTENDED SERIAL NUMBER

If XSER = 0, the four Most Significant bits of the Serial Number are substituted by S[3:0] and the code word format is compatible with the HCS200/300/301.

If XSER = 1, the full 32-bit Serial Number [SER_1, SER_0] is transmitted.

Note:	Since the button status S[3:0] is used to detect a Seed transmission, Extended Serial Number and Secure Learn are mutually exclusive.

3.5.6 DISCRIMINATION VALUE

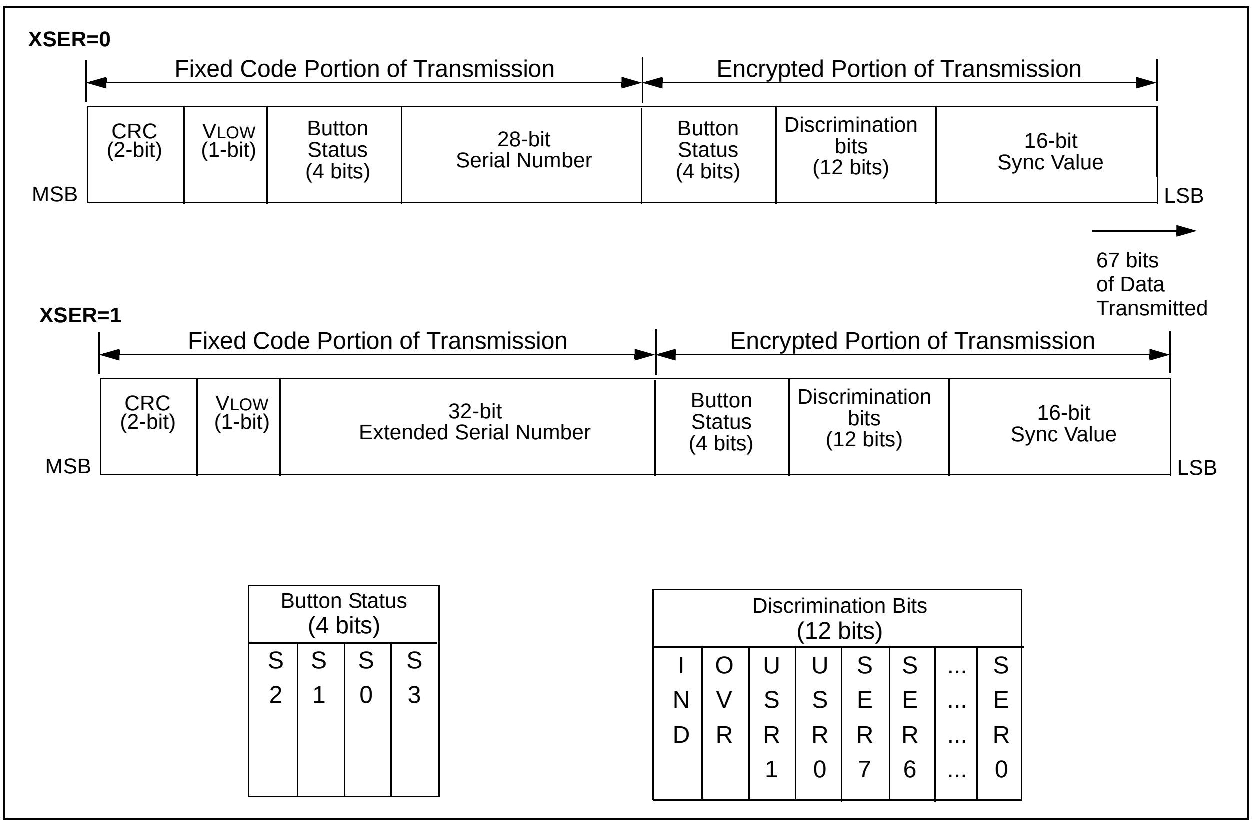
While in other KEELOQ encoders its value is user selectable, the HCS360 uses directly the 8 Least Significant bits of the Serial Number as part of the information that form the encrypted portion of the transmission (Figure 3-1).

The discrimination value aids the post-decryption check on the decoder end. After the receiver has decrypted a transmission, the discrimination bits are checked against the encoder Serial Number to verify that the decryption process was valid.

3.5.7 USRA,B: USER BITS

User bits form part of the discrimination value. The user bits together with the IND bit can be used to identify the counter that is used in Independent mode.

FIGURE 3-1: CODE WORD ORGANIZATION



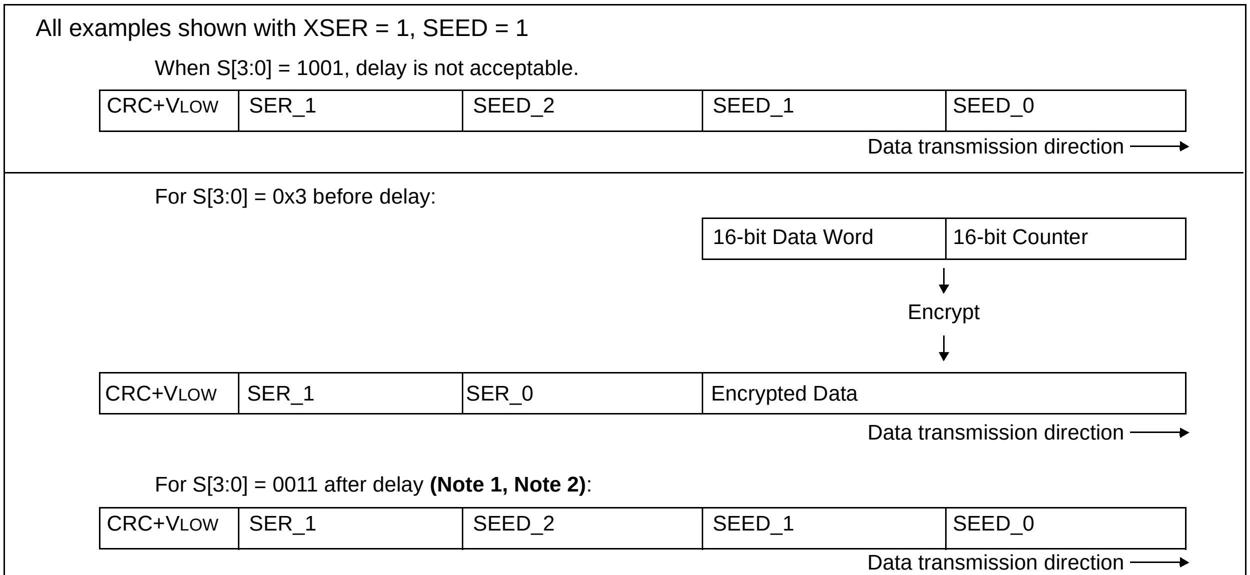
3.5.8 SEED: ENABLE SEED TRANSMISSION

If SEED = 0, seed transmission is disabled. The Independent Counter mode can only be used with seed transmission disabled since SEED_2 is shared with the second synchronization counter.

With SEED = 1, seed transmission is enabled. The appropriate button code(s) must be activated to transmit the seed information. In this mode, the seed information (SEED_0, SEED_1, and SEED_2) and the upper 12 or 16 bits of the serial number (SER_1) are transmitted instead of the hop code.

Seed transmission is available for function codes (Table 3-9) S[3:0] = 1001 and S[3:0] = 0011(delayed). This takes place regardless of the setting of the IND bit. The two seed transmissions are shown in Figure 3-2.

FIGURE 3-2: Seed Transmission



Note 1: For Seed Transmission, SEED_2 is transmitted instead of SER_0.
2: For Seed Transmission, the setting of DELM has no effect.

3.5.9 TMPSD: TEMPORARY SEED TRANSMISSION

The temporary seed transmission can be used to disable learning after the transmitter has been used for a programmable number of operations. This feature can be used to implement very secure systems. After learning is disabled, the seed information cannot be accessed even if physical access to the transmitter is possible. If TMPSD = 1 the seed transmission will be disabled after a number of code hopping transmissions. The number of transmissions before seed transmission is disabled, can be programmed by setting the synchronization counter (SYNC_A, SYNC_B) to a value as shown in Table 3-5.

TABLE 3-5: SYNCHRONOUS COUNTER INITIALIZATION VALUES

Synchronous Counter Values	Number of Transmissions
0000H	128
0060H	64
0050H	32
0048H	16

3.5.10 DELM: DELAY MODE

If DELM = 1, delay transmission is enabled. A delayed transmission is indicated by inverting the lower nibble of the discrimination value. The Delay mode is primarily for compatibility with previous KEELOQ devices and is not recommended for new designs.

If DELM = 0, delay transmission is disabled (Table 3-6).

TABLE 3-6: TYPICAL DELAY TIMES

BSEL 1	BSEL 0	Number of Code Words before Delay Mode	Time Before Delay Mode (MOD = 0)	Time Before Delay Mode (MOD = 1)
0	0	28	≈ 2.9s	≈ 5.1s
0	1	56	≈ 3.1s	≈ 6.4s
1	0	28	≈ 1.5s	≈ 3.2s
1	1	56	≈ 1.7s	≈ 4.5s

3.5.11 TIMO: TIME-OUT OR AUTO-SHUTOFF

If TIMO = 1, the time-out is enabled. Time-out can be used to terminate accidental continuous transmissions. When time-out occurs, the PWM output is set low and the LED is turned off. Current consumption will be higher than in Standby mode since current will flow through the activated input resistors. This state can be exited only after all inputs are taken low. TIMO = 0, will enable continuous transmission (Table 3-7).

TABLE 3-7: TYPICAL TIME-OUT TIMES

BSEL 1	BSEL 0	Maximum Number of Code Words Transmitted	Time Before Time-out (MOD = 0)	Time Before Time-out (MOD = 1)
0	0	256	≈ 26.5s	≈ 46.9
0	1	512	≈ 28.2s	≈ 58.4
1	0	256	≈ 14.1s	≈ 29.2
1	1	512	≈ 15.7s	≈ 40.7

3.5.12 IND: INDEPENDENT MODE

The Independent mode can be used where one encoder is used to control two receivers. Two counters (SYNC_A and SYNC_B) are used in Independent mode. As indicated in Table 3-9, function codes 1 to 7 use SYNC_A and 8 to 15 SYNC_B.

3.5.13 INFRARED MODE

The Independent mode also selects IR mode. In IR mode function codes 12 to 15 will use SYNC_B. The PWM output signal is modulated with a 40 kHz carrier (see Table 3-8). It must be pointed out that the 40 kHz is derived from the internal clock and will therefore vary with the same percentage as the baud rate. If IND = 0, SYNC_A is used for all function codes. If IND = 1, Independent mode is enabled and counters for functions are used according to Table 3-9.

TABLE 3-8: IR MODULATION

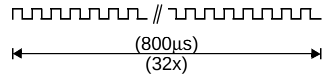
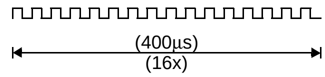
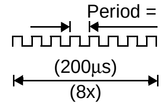
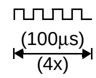
TE	Basic Pulse
800us	 (800µs) (32x)
400us	 (400µs) (16x)
200us	 Period = 25µs (200µs) (8x)
100us	 (100µs) (4x)

TABLE 3-9: FUNCTION CODES

	S3	S2	S1	S0	IND = 0	IND = 1	Comments
					Counter		
1	0	0	0	1	A	A	
2	0	0	1	0	A	A	
3	0	0	1	1	A	A	If SEED = 1, transmit seed after delay.
4	0	1	0	0	A	A	
5	0	1	0	1	A	A	
6	0	1	1	0	A	A	
7	0	1	1	1	A	A	
8	1	0	0	0	A	B	
9	1	0	0	1	A	B	If SEED = 1, transmit seed immediately.
10	1	0	1	0	A	B	
11	1	0	1	1	A	B	
12	1	1	0	0	A	B(1)	
13	1	1	0	1	A	B(1)	
14	1	1	1	0	A	B(1)	
15	1	1	1	1	A	B(1)	

Note 1: IR mode

4.0 TRANSMITTED WORD

4.1 Transmission Format (PWM)

The HCS360 code word is made up of several parts (Figure 4-1 and Figure 4-2). Each code word contains a 50% duty cycle preamble, a header, 32 bits of encrypted data and 35 bits of fixed data followed by a guard period before another code word can begin. Refer to Table 8-3 and Table 8-5 for code word timing.

4.2 Code Word Organization

The HCS360 transmits a 67-bit code word when a button is pressed. The 67-bit word is constructed from a Fixed Code portion and an Encrypted Code portion (Figure 3-1).

The **Encrypted Data** is generated from 4 function bits, 2 user bits, overflow bit, Independent mode bit, and 8 serial number bits, and the 16-bit synchronization value (Figure 3-1). The encrypted portion alone provides up to four billion changing code combinations.

The **Fixed Code Data** is made up of a VLOW bit, 2 CRC bits, 4 function bits, and the 28-bit serial number. If the extended serial number (32 bits) is selected, the 4 function code bits will not be transmitted. The fixed and encrypted sections combined increase the number of code combinations to 7.38 x 10^{19}

FIGURE 4-1: CODE WORD FORMAT (PWM)

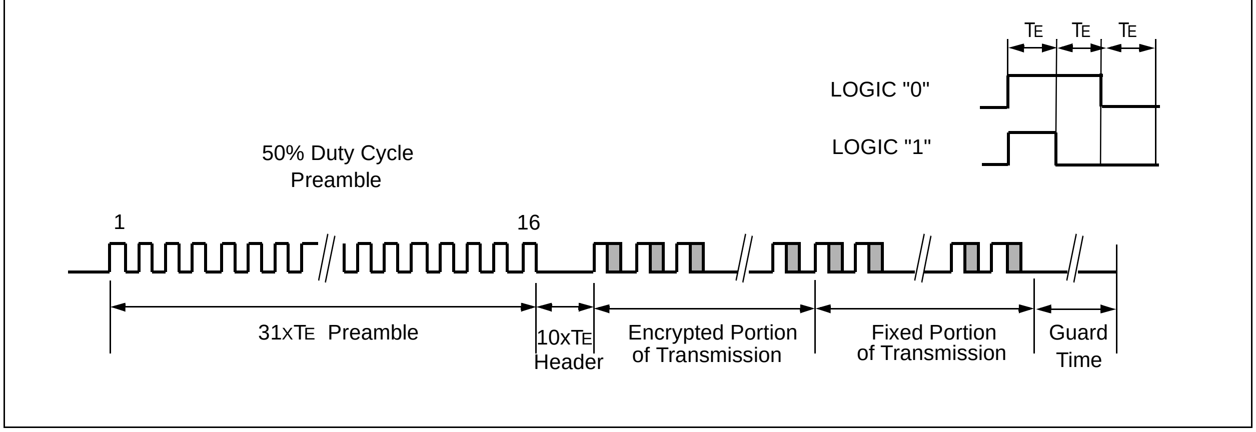
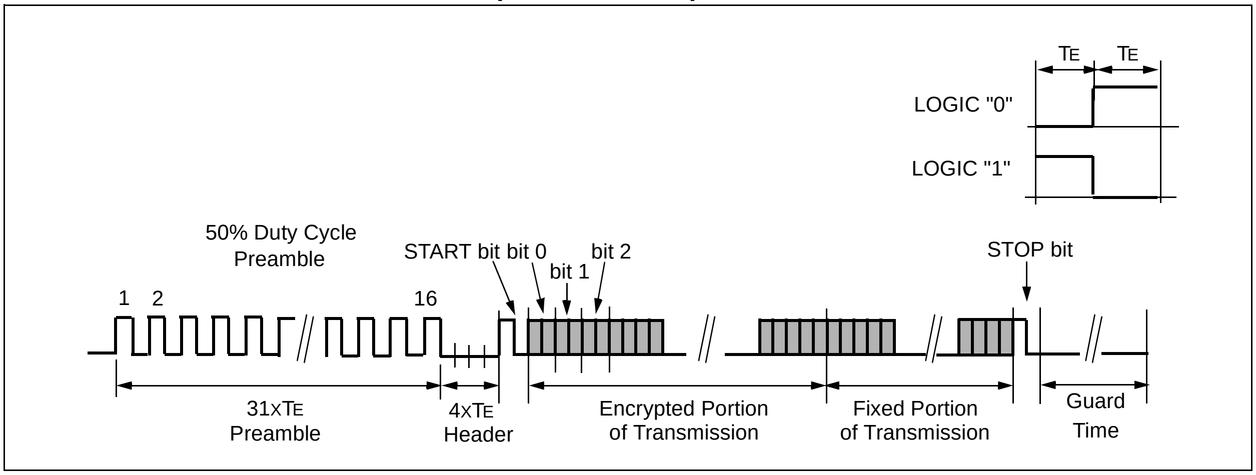


FIGURE 4-2: CODE WORD FORMAT (MANCHESTER)



5.0 SPECIAL FEATURES

5.1 Code Word Completion

Code word completion is an automatic feature that ensures that the entire code word is transmitted, even if the button is released before the transmission is complete and that a minimum of two words are completed. The HCS360 encoder powers itself up when a button is pushed and powers itself down after two complete words are transmitted if the user has already released the button. If the button is held down beyond the time for one transmission, then multiple transmissions will result. If another button is activated during a transmission, the active transmission will be aborted and the new code will be generated using the new button information.

5.2 Long Guard Time

Federal Communications Commission (FCC) part 15 rules specify the limits on fundamental power and harmonics that can be transmitted. Power is calculated on the worst case average power transmitted in a 100 ms window. It is therefore advantageous to minimize the duty cycle of the transmitted word. This can be achieved by minimizing the duty cycle of the individual bits or by extending the guard time between transmissions. Long guard time (LNGRD) is used for reducing the average power of a transmission. This is a selectable feature. Using the LNGRD allows the user to transmit a higher amplitude transmission if the transmission time per 100 ms is shorter. The FCC puts constraints on the average power that can be transmitted by a device, and LNGRD effectively prevents continuous transmission by only allowing the transmission of every second word. This reduces the average power transmitted and hence, assists in FCC approval of a transmitter device.

5.3 CRC (Cycle Redundancy Check) Bits

The CRC bits are calculated on the 65 previously transmitted bits. The CRC bits can be used by the receiver to check the data integrity before processing starts. The CRC can detect all single bit and 66% of double bit errors. The CRC is computed as follows:

EQUATION 5-1: CRC Calculation

$$CRC[1]_{n+1} = CRC[0]_n \wedge Di_n$$

and

$$CRC[0]_{n+1} = (CRC[0]_n \wedge Di_n) \wedge CRC[1]_n$$

with

$$CRC[1,0]_0 = 0$$

and

Di_n the nth transmission bit $0 \le n \le 64$

> **Note:** The CRC may be wrong when the battery voltage is around either of the VLOW trip points. This may happen because VLOW is sampled twice each transmission, once for the CRC calculation (PWM is low) and once when VLOW is transmitted (PWM is high). VDD tends to move slightly during a transmission which could lead to a different value for VLOW being used for the CRC calculation and the transmission
>
> . Work around: If the CRC calculation is incorrect, recalculate for the opposite value of VLOW.

5.4 Auto-shutoff

The Auto-shutoff function automatically stops the device from transmitting if a button inadvertently gets pressed for a long period of time. This will prevent the device from draining the battery if a button gets pressed while the transmitter is in a pocket or purse. This function can be enabled or disabled and is selected by setting or clearing the time-out bit (Section 3.5.11). Setting this bit will enable the function (turn Auto-shutoff function on) and clearing the bit will disable the function. Time-out period is approximately 25 seconds.

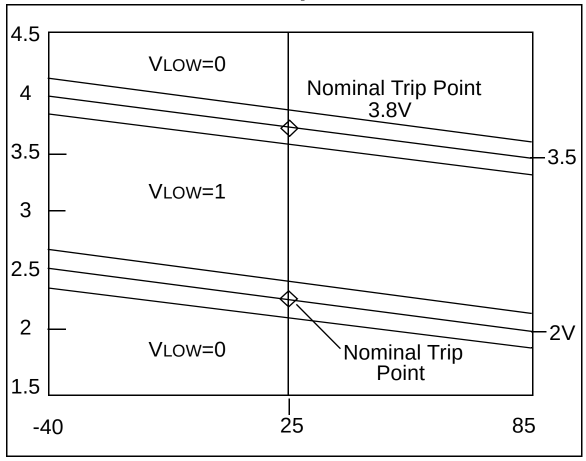
5.5 VLOW: Voltage LOW Indicator

The VLOW bit is transmitted with every transmission (Figure 3-1) and will be transmitted as a one if the operating voltage has dropped below the low voltage trip point, typically 3.8V at 25°C. This VLOW signal is transmitted so the receiver can give an indication to the user that the transmitter battery is low.

5.6 $\overline{\text{LED}}$ Output Operation

During normal transmission the $\overline{\text{LED}}$ output is LOW while the data is being transmitted and high during the guard time. Two voltage indications are combined into one bit: VLOW. Table 5-1 indicates the operation value of VLOW while data is being transmitted.

FIGURE 5-1: VLOW Trip Point VS. Temperature



If the supply voltage drops below the low voltage trip point, the $\overline{\text{LED}}$ output will be toggled at approximately 1Hz during the transmission.

TABLE 5-1: VLOW AND LED VS. VDD

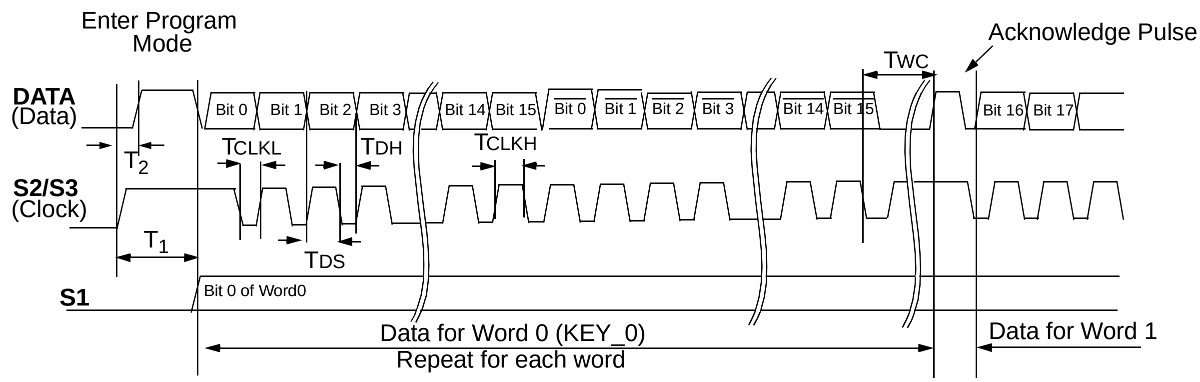
Approximate Supply Voltage	VLOW Bit	LED Operation*
Max → 3.8V	0	Normal
3.8V → 2.2V	1	Flashing
2.2V → Min	0	Normal

*See also FLASH operating modes.

6.0 PROGRAMMING THE HCS360

When using the HCS360 in a system, the user will have to program some parameters into the device including the serial number and the secret key before it can be used. The programming allows the user to input all 192 bits in a serial data stream, which are then stored internally in EEPROM. Programming will be initiated by forcing the PWM line high, after the S3 line has been held high for the appropriate length of time. S0 should be held low during the entire program cycle. The S1 line on the HCS360 part needs to be set or cleared depending on the LS bit of the memory map (Key 0) before the key is clocked in to the HCS360. S1 must remain at this level for the duration of the programming cycle. The device can then be programmed by clocking in 16 bits at a time, followed by the word's complement using S3 or S2 as the clock line and PWM as the data in line. After each 16-bit word is loaded, a programming delay is required for the internal program cycle to complete. The Acknowledge can read back after the programming delay (TWC). After the first word and its complement have been downloaded, an automatic bulk write is performed. This delay can take up to Twc. At the end of the programming cycle, the device can be verified (Figure 6-1) by reading back the EEPROM. Reading is done by clocking the S3 line and reading the data bits on PWM. For security reasons, it is not possible to execute a Verify function without first programming the EEPROM. **A Verify operation can only be done once, immediately following the Program cycle**.

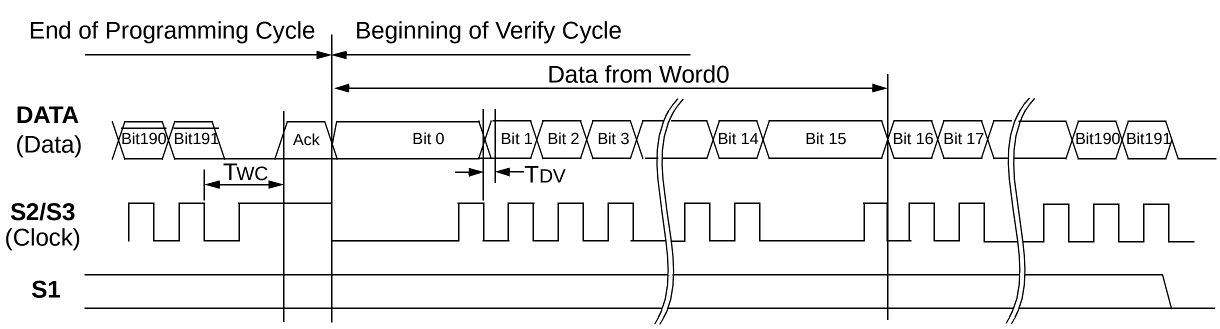
FIGURE 6-1: Programming Waveforms



Note 1: Unused button inputs to be held to ground during the entire programming sequence.

2: The VDD pin must be taken to ground after a Program/Verify cycle.

FIGURE 6-2: Verify Waveforms



Note: A Verify sequence is performed only once immediately after the Program cycle.

TABLE 6-3: PROGRAMMING/VERIFY TIMING REQUIREMENTS

V_{DD} = 5.0V ± 10%
25° C ± 5 °C

Parameter	Symbol	Min.	Max.	Units
Program mode setup time	T_2	0	4.0	ms
Hold time 1	T_1	9.0	—	ms
Program cycle time	T_{WC}	50	—	ms
Clock low time	T_{CLKL}	50	—	µs
Clock high time	T_{CLKH}	50	—	µs
Data setup time	T_{DS}	0	—	µs(1)
Data hold time	T_{DH}	30	—	µs(1)
Data out valid time	T_{DV}	—	30	µs(1)

Note 1: Typical values - not tested in production.

7.0 INTEGRATING THE HCS360 INTO A SYSTEM

Use of the HCS360 in a system requires a compatible decoder. This decoder is typically a microcontroller with compatible firmware. Microchip will provide (via a license agreement) firmware routines that accept transmissions from the HCS360 and decrypt the hopping code portion of the data stream. These routines provide system designers the means to develop their own decoding system.

7.1 Learning a Transmitter to a Receiver

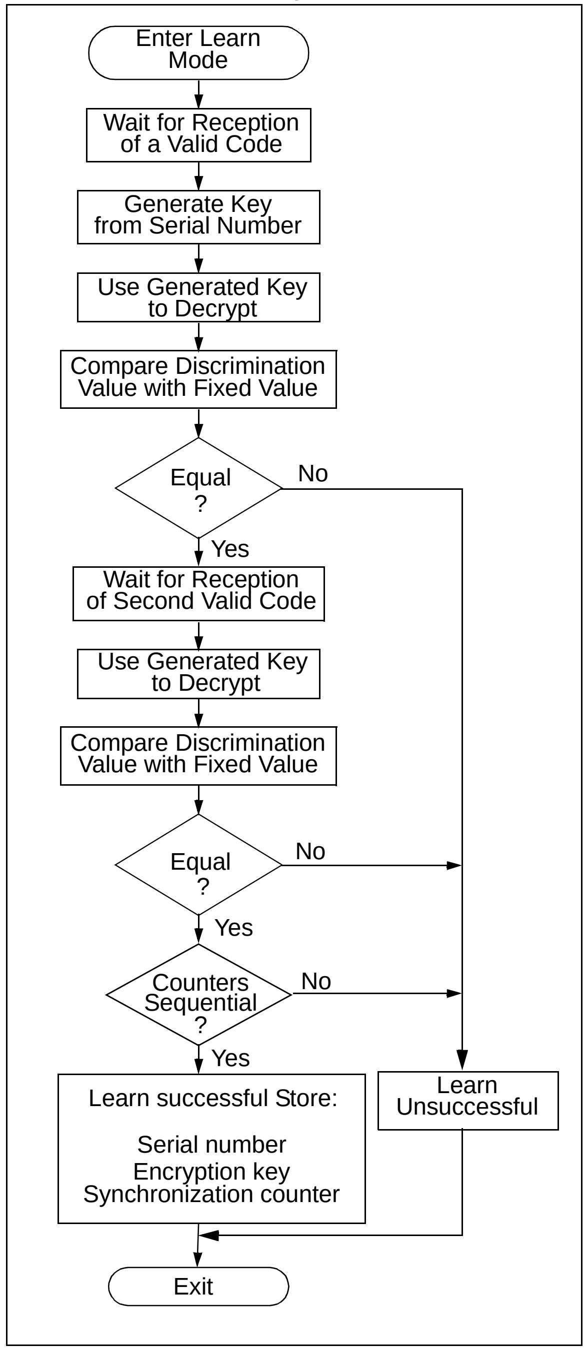
A transmitter must first be 'learned' by a decoder before its use is allowed in the system. Several learning strategies are possible, Figure 7-1 details a typical learn sequence. Core to each, the decoder must minimally store each learned transmitter's serial number and current synchronization counter value in EEPROM. Additionally, the decoder typically stores each transmitter's unique crypt key. The maximum number of learned transmitters will therefore be relative to the available EEPROM.

A transmitter's serial number is transmitted in the clear but the synchronization counter only exists in the code word's encrypted portion. The decoder obtains the counter value by decrypting using the same key used to encrypt the information. The KEELOQ algorithm is a symmetrical block cipher so the encryption and decryption keys are identical and referred to generally as the crypt key. The encoder receives its crypt key during manufacturing. The decoder is programmed with the ability to generate a crypt key as well as all but one required input to the key generation routine; typically the transmitter's serial number.

Figure 7-1 summarizes a typical learn sequence. The decoder receives and authenticates a first transmission; first button press. Authentication involves generating the appropriate crypt key, decrypting, validating the correct key usage via the discrimination bits and buffering the counter value. A second transmission is received and authenticated. A final check verifies the counter values were sequential; consecutive button presses. If the learn sequence is successfully complete, the decoder stores the learned transmitter's serial number, current synchronization counter value and appropriate crypt key. From now on the crypt key will be retrieved from EEPROM during normal operation instead of recalculating it for each transmission received.

Certain learning strategies have been patented and care must be taken not to infringe.

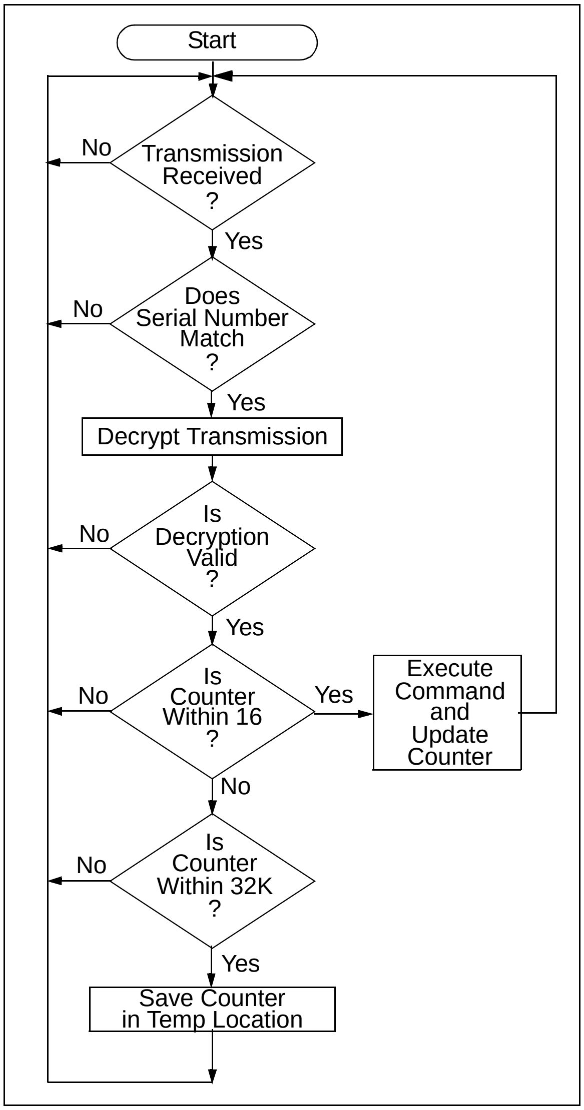
FIGURE 7-1: TYPICAL LEARN SEQUENCE



7.2 Decoder Operation

Figure 7-2 summarizes normal 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 learned transmitter, the transmission is decrypted using the stored crypt key and authenticated via the discrimination bits for appropriate crypt key usage. If the decryption was valid the synchronization value is evaluated.

FIGURE 7-2: TYPICAL DECODER OPERATION



7.3 Synchronization with Decoder (Evaluating the Counter)

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

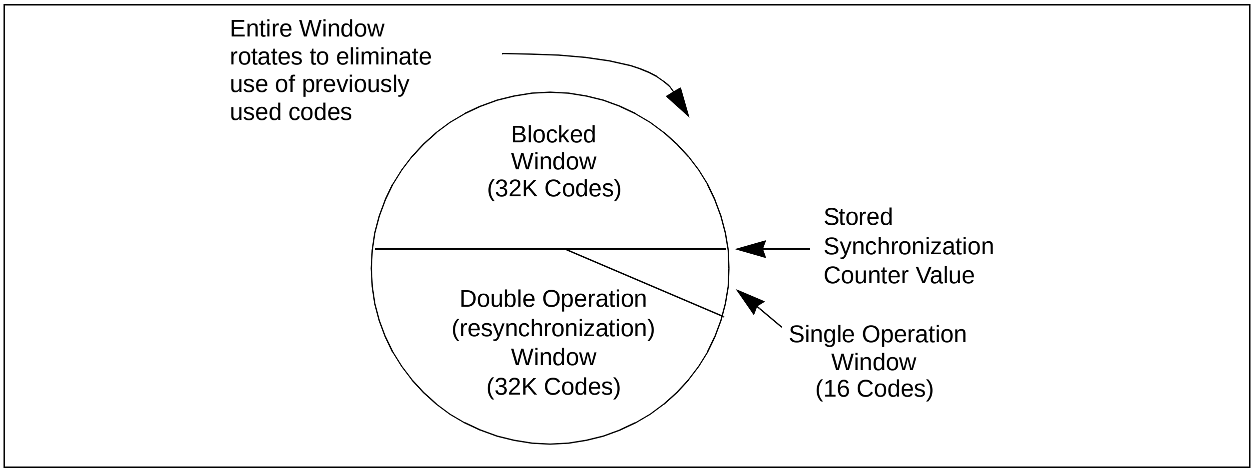
Figure 7-3 shows a 3-partition, rotating synchronization window. The size of each window is optional but the technique is fundamental. Each time a transmission is authenticated, the intended function is executed and the transmission's synchronization counter value is stored in EEPROM. From the currently 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 the 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 codes forward of the currently stored counter value. It is referred to as "Double Operation" because a transmission with synchronization counter value 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, perhaps code-grabbed transmissions from accessing the system.

Note:	The synchronization method described in this section is only a typical implementation and because it is usually implemented in firmware, it can be altered to fit the needs of a particular system.

FIGURE 7-3: SYNCHRONIZATION WINDOW



8.0 ELECTRICAL CHARACTERISTICS

TABLE 8-1: ABSOLUTE MAXIMUM RATINGS

Symbol	Item	Rating	Units
V_{DD}	Supply voltage	-0.3 to 6.9	V
V_{IN}	Input voltage	-0.3 to V_{DD} + 0.3	V
V_{OUT}	Output voltage	-0.3 to V_{DD} + 0.3	V
I_{OUT}	Max output current	25	mA
T_{STG}	Storage temperature	-55 to +125	°C **(Note)**
T_{LSOL}	Lead soldering temp	300	°C **(Note)**
V_{ESD}	ESD rating	4000	V

Note: Stresses above those listed under “ABSOLUTE MAXIMUM RATINGS” may cause permanent damage to the device.

TABLE 8-2: DC CHARACTERISTICS

Commercial (C): Tamb = 0°C to +70°C
Industrial (I): Tamb = -40°C to +85°C

		2.0V < V_{DD} < 3.3			3.0 < V_{DD} < 6.6				
Parameter	**Sym.**	**Min**	**Typ[1]**	**Max**	**Min**	**Typ[1]**	**Max**	**Unit**	**Conditions**
Operating current (avg)	I_{CC}		0.3	1.2		0.7	1.6	mA	V_{DD} = 3.3V V_{DD} = 6.6V
Standby current	I_{CCS}		0.1	1.0		0.1	1.0	μA	
Auto-shutoff current[2,3]	I_{CCS}		40	75		160	350	μA	
High level input voltage	V_{IH}	0.55 V_{DD}		V_{DD}+0.3	0.55V_{DD}		V_{DD}+0.3	V	
Low level input voltage	V_{IL}	-0.3		0.15 V_{DD}	-0.3		0.15V_{DD}	V	
High level output voltage	V_{OH}	0.7 V_{DD}			0.7V_{DD}			V	I_{OH} = -1.0 mA, V_{DD} = 2.0V I_{OH} = -2.0 mA, V_{DD} = 6.6V
Low level output voltage	V_{OL}			0.08 V_{DD}			0.08V_{DD}	V	I_{OL} = 1.0 mA, V_{DD} = 2.0V I_{OL} = 2.0 mA, V_{DD} = 6.6V
$\overline{\text{LED}}$ sink current	I_{LED}	0.15	1.0	4.0	0.15	1.0	4.0	mA	V_{LED}[4] = 1.5V, V_{DD} = 6.6V
Pull-Down Resistance; S0-S3	R_{S0-3}	40	60	80	40	60	80	kΩ	V_{DD} = 4.0V
Pull-Down Resistance; DATA	R_{PWM}	80	120	160	80	120	160	kΩ	V_{DD} = 4.0V

Note 1: Typical values are at 25°C.
2: Auto-shutoff current specification does not include the current through the input pull-down resistors.
3: Auto-shutoff current is periodically sampled and not 100% tested.
4: V_{LED} is the voltage between the V_{DD} pin and the $\overline{\text{LED}}$ pin.

FIGURE 8-1: POWER-UP AND TRANSMIT TIMING

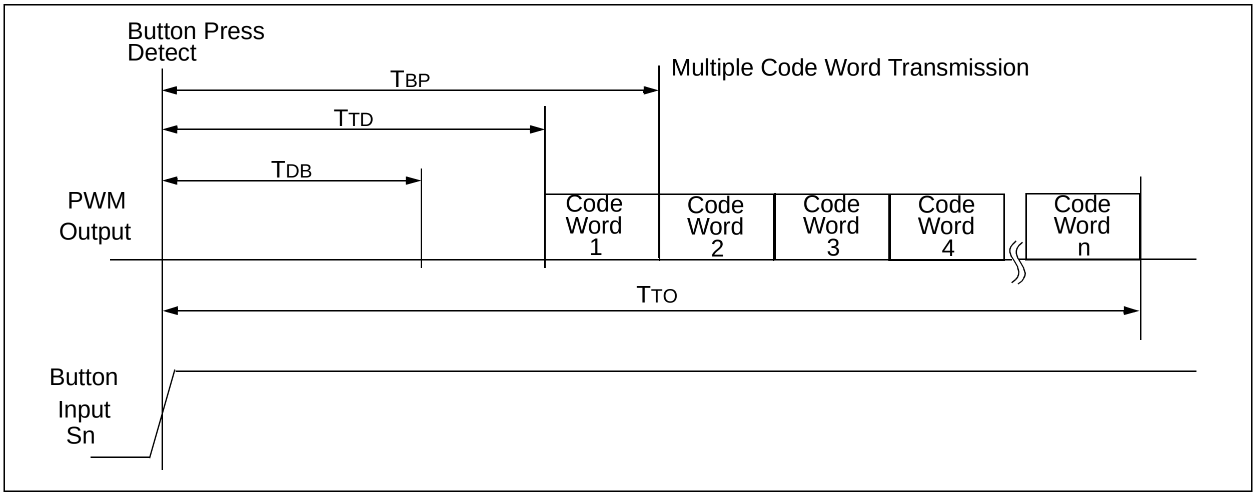


FIGURE 8-2: POWER-UP AND TRANSMIT TIMING REQUIREMENTS

VDD = +2.0 to 6.6V
Commercial (C): Tamb = 0°C to +70°C
Industrial (I): Tamb = -40°C to +85°C

Parameter	Symbol	Min	Max	Unit	Remarks
Time to second button press	TBP	10 + Code Word Time	26 + Code Word Time	ms	**(Note 1)**
Transmit delay from button detect	TTD	4.5	26	ms	**(Note 2)**
Debounce delay	TDB	4.0	13	ms	
Auto-shutoff time-out period	TTO	15.0	35	s	**(Note 3)**

Note 1: TBP is the time in which a second button can be pressed without completion of the first code word and the intention was to press the combination of buttons.
2: Transmit delay maximum value if the previous transmission was successfully transmitted.
3: The Auto-shutoff time-out period is not tested.

FIGURE 8-3: PWM FORMAT SUMMARY (MOD=0)

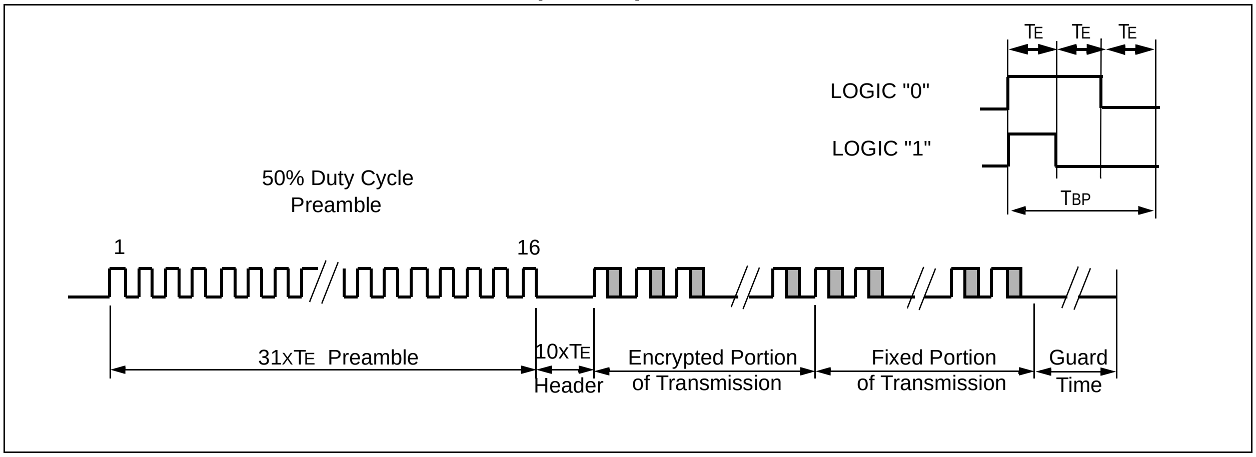


FIGURE 8-4: PWM PREAMBLE/HEADER FORMAT (MOD=0)

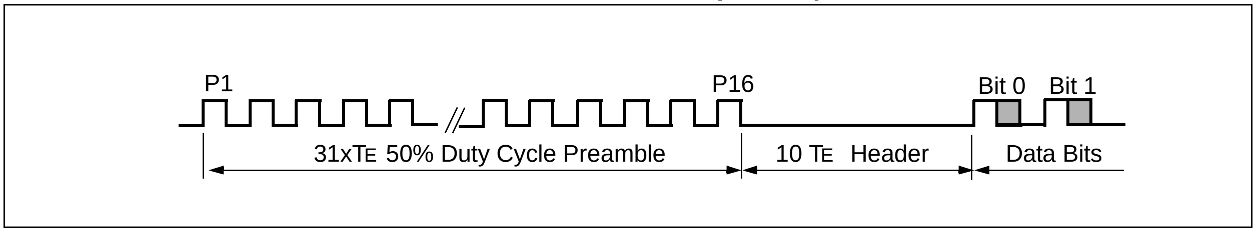


FIGURE 8-5: PWM DATA FORMAT (MOD=0)

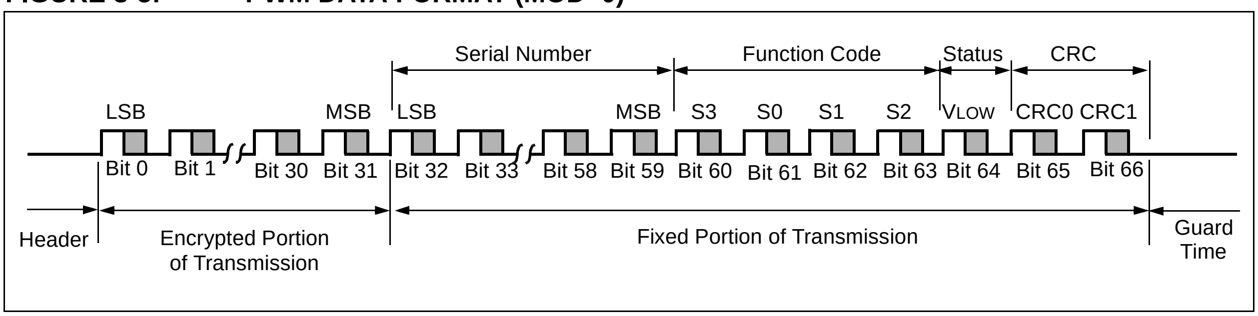


FIGURE 8-6: MANCHESTER FORMAT SUMMARY (MOD=1)

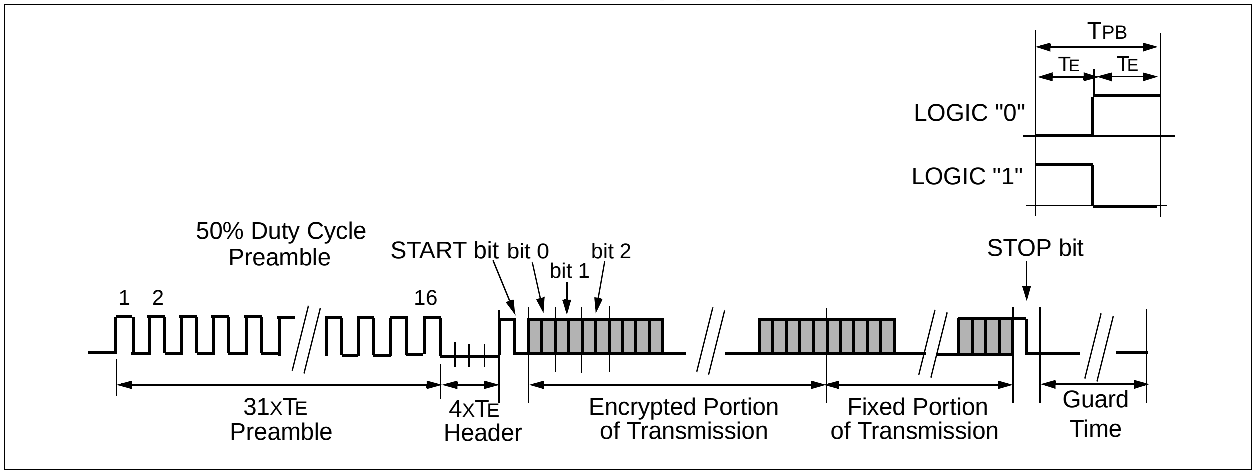


FIGURE 8-7: MANCHESTER PREAMBLE/HEADER FORMAT (MOD=1)

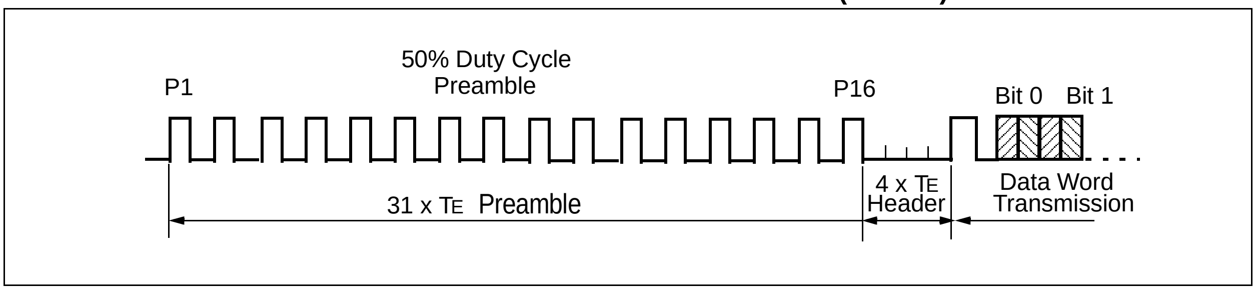


FIGURE 8-8: HCS360 NORMALIZED TE VS. TEMP

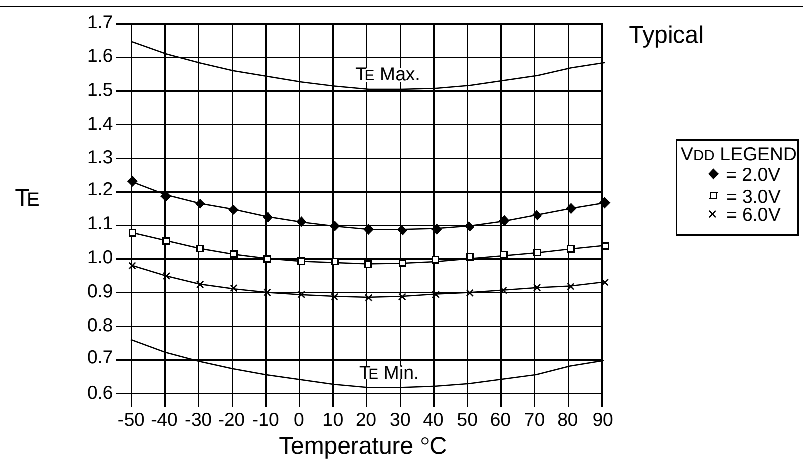


TABLE 8-3: CODE WORD TRANSMISSION TIMING PARAMETERS—PWM MODE

VDD = +2.0V to 6.6V Commercial (C):Tamb = 0°C to +70°C Industrial (I):Tamb = -40°C to +85°C		Code Words Transmitted						
		BSEL1 = 0 BSEL0 = 0			BSEL1 = 0 BSEL0 = 1			
Symbol	**Characteristic**	**Min.**	**Typ.**	**Max.**	**Min.**	**Typ.**	**Max.**	**Units**
TE	Basic pulse element	260	400	620	130	200	310	µs
TBP	PWM bit pulse width		3			3		TE
TP	Preamble duration		31			31		TE
TH	Header duration		10			10		TE
THOP	Hopping code duration		96			96		TE
TFIX	Fixed code duration		105			105		TE
TG	Guard Time (LNGRD = 0)		17			33		TE
—	Total transmit time		259			275		TE
—	Total transmit time	67.3	103.6	160.6	35.8	55.0	85.3	ms
—	PWM data rate	1282	833	538	2564	1667	1075	bps

Note: The timing parameters are not tested but derived from the oscillator clock.

TABLE 8-4: CODE WORD TRANSMISSION TIMING PARAMETERS—PWM MODE

VDD = +2.0V to 6.6V Commercial (C):Tamb = 0°C to +70°C Industrial (I):Tamb = -40°C to +85°C		Code Words Transmitted						
		BSEL1 = 1, BSEL0 = 0			BSEL1 = 1, BSEL0 = 1			
Symbol	**Characteristic**	**Min.**	**Typ.**	**Max.**	**Min.**	**Typ.**	**Max.**	**Units**
TE	Basic pulse element	130	200	310	65	100	155	µs
TBP	PWM bit pulse width		3			3		TE
TP	Preamble duration		31			31		TE
TH	Header duration		10			10		TE
THOP	Hopping code duration		96			96		TE
TFIX	Fixed code duration		105			105		TE
TG	Guard Time (LNGRD = 0)		33			65		TE
—	Total transmit time		275			307		TE
—	Total transmit time	35.8	55.0	85.3	20.0	30.7	47.6	ms
—	PWM data rate	2564	1667	1075	5128	3333	2151	bps

Note: The timing parameters are not tested but derived from the oscillator clock.

TABLE 8-5: CODE WORD TRANSMISSION TIMING PARAMETERS—MANCHESTER MODE

VDD = +2.0V to 6.6V Commercial (C):Tamb = 0°C to +70°C Industrial (I):Tamb = -40°C to +85°C		Code Words Transmitted						
		BSEL1 = 0, BSEL0 = 0			BSEL1 = 0. BSEL0 = 1			
Symbol	**Characteristic**	**Min.**	**Typ.**	**Max.**	**Min.**	**Typ.**	**Max.**	**Units**
TE	Basic pulse element	520	800	1240	260	400	620	µs
TP	Preamble duration		31			31		TE
TH	Header duration		4			4		TE
TSTART	START bit		2			2		TE
THOP	Hopping code duration		64			64		TE
TFIX	Fixed code duration		70			70		TE
TSTOP	STOP bit		2			2		TE
TG	Guard Time (LNGRD = 0)		9			17		TE
—	Total transmit time		182			190		TE
—	Total transmit time	94.6	145.6	223.7	49.4	76.0	117.8	ms
—	Manchester data rate	1923	1250	806	3846.2	2500	1612.9	bps

Note: The timing parameters are not tested but derived from the oscillator clock.

TABLE 8-6: CODE WORD TRANSMISSION TIMING PARAMETERS—MANCHESTER MODE

VDD = +2.0V to 6.6V Commercial (C):Tamb = 0°C to +70°C Industrial (I):Tamb = -40°C to +85°C		Code Words Transmitted						
		BSEL1 = 1, BSEL0 = 0			BSEL1 = 1. BSEL0 = 1			
Symbol	**Characteristic**	**Min.**	**Typ.**	**Max.**	**Min.**	**Typ.**	**Max.**	**Units**
TE	Basic pulse element	260	400	620	130	200	310	µs
TP	Preamble duration		32			32		TE
TH	Header duration		4			4		TE
TSTART	START bit		2			2		TE
THOP	Hopping code duration		64			64		TE
TFIX	Fixed code duration		70			70		TE
TSTOP	STOP bit		2			2		TE
TG	Guard Time (LNGRD = 0)		16			32		TE
—	Total transmit time		190			206		TE
—	Total transmit time	49.4	76.0	117.8	26.8	41.2	63.4	ms
—	Manchester data rate	3846.2	2500.0	1612.9	7692.3	5000.0	3225.8	bps

Note: The timing parameters are not tested but derived from the oscillator clock.

9.0 PACKAGING INFORMATION

9.1 Package Marking Information

8-Lead PDIP (300 mil)	Example
XXXXXXXX XXXXXNNN YYWW	HCS360 XXXXXNNN 0025

8-Lead SOIC (150 mil)	Example
XXXXXXX XXXYYWW NNN	HCS360 XXX0025 NNN

Legend:

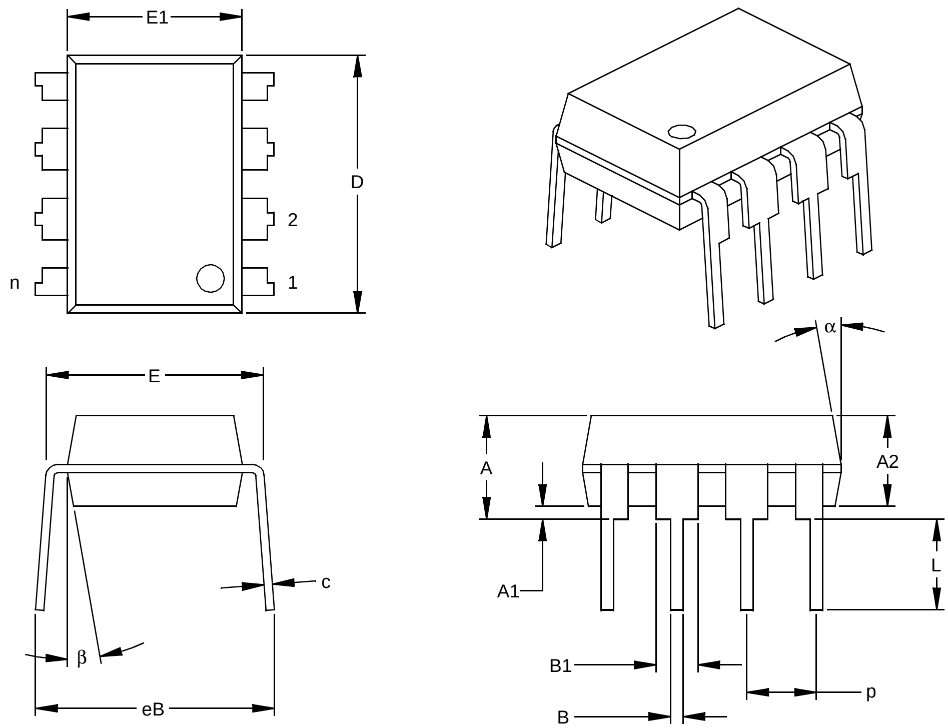
XX...X	Customer specific information*
Y	Year code (last digit of calendar year)
YY	Year code (last 2 digits of calendar year)
WW	Week code (week of January 1 is week '01')
NNN	Alphanumeric traceability code

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 PICmicro device marking consists of Microchip part number, year code, week code, and traceability code. For PICmicro 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.

9.2 Package Details

8-Lead Plastic Dual In-line (P) - 300 mil (PDIP)

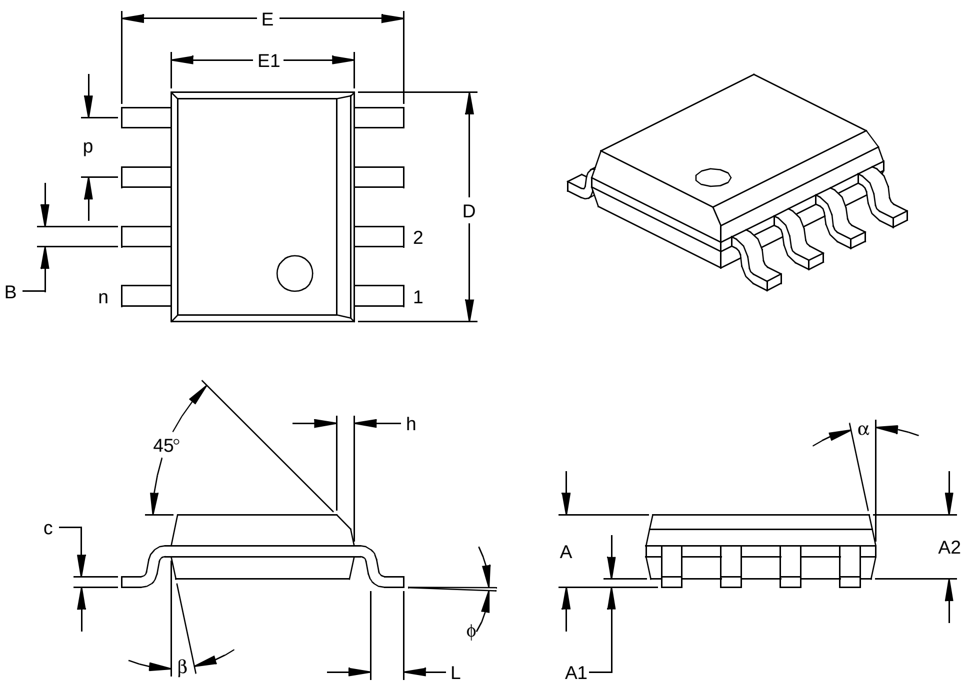


	Units	INCHES*			MILLIMETERS		
	Dimension Limits	MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.100			2.54	
Top to Seating Plane	A	.140	.155	.170	3.56	3.94	4.32
Molded Package Thickness	A2	.115	.130	.145	2.92	3.30	3.68
Base to Seating Plane	A1	.015			0.38		
Shoulder to Shoulder Width	E	.300	.313	.325	7.62	7.94	8.26
Molded Package Width	E1	.240	.250	.260	6.10	6.35	6.60
Overall Length	D	.360	.373	.385	9.14	9.46	9.78
Tip to Seating Plane	L	.125	.130	.135	3.18	3.30	3.43
Lead Thickness	c	.008	.012	.015	0.20	0.29	0.38
Upper Lead Width	B1	.045	.058	.070	1.14	1.46	1.78
Lower Lead Width	B	.014	.018	.022	0.36	0.46	0.56
Overall Row Spacing §	eB	.310	.370	.430	7.87	9.40	10.92
Mold Draft Angle Top	α	5	10	15	5	10	15
Mold Draft Angle Bottom	β	5	10	15	5	10	15

* Controlling Parameter
§ Significant Characteristic

Notes:
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.
JEDEC Equivalent: MS-001
Drawing No. C04-018

8-Lead Plastic Small Outline (SN) - Narrow, 150 mil (SOIC)



Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.050			1.27	
Overall Height	A	.053	.061	.069	1.35	1.55	1.75
Molded Package Thickness	A2	.052	.056	.061	1.32	1.42	1.55
Standoff §	A1	.004	.007	.010	0.10	0.18	0.25
Overall Width	E	.228	.237	.244	5.79	6.02	6.20
Molded Package Width	E1	.146	.154	.157	3.71	3.91	3.99
Overall Length	D	.189	.193	.197	4.80	4.90	5.00
Chamfer Distance	h	.010	.015	.020	0.25	0.38	0.51
Foot Length	L	.019	.025	.030	0.48	0.62	0.76
Foot Angle	φ	0	4	8	0	4	8
Lead Thickness	c	.008	.009	.010	0.20	0.23	0.25
Lead Width	B	.013	.017	.020	0.33	0.42	0.51
Mold Draft Angle Top	α	0	12	15	0	12	15
Mold Draft Angle Bottom	β	0	12	15	0	12	15

* Controlling Parameter
§ Significant Characteristic

Notes:
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.
JEDEC Equivalent: MS-012
Drawing No. C04-057

ON-LINE SUPPORT

Microchip provides on-line support on the Microchip World Wide Web (WWW) site.

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The Microchip web site is available by using your favorite Internet browser to attach to:

www.microchip.com

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The web site and file transfer site provide a variety of services. Users may download files for the latest Development Tools, Data Sheets, Application Notes, User's Guides, Articles and Sample Programs. A variety of Microchip specific business information is also available, including listings of Microchip sales offices, distributors and factory representatives. Other data available for consideration is:

- Latest Microchip Press Releases
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- Design Tips
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- Listing of seminars and events

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The Systems Information and Upgrade Line provides system users a listing of the latest versions of all of Microchip's development systems software products. Plus, this line provides information on how customers can receive any currently available upgrade kits.The Hot Line Numbers are:

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Device: **HCS360**　　Literature Number: **DS40152E**

Questions:

1. What are the best features of this document?

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2. How does this document meet your hardware and software development needs?

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3. Do you find the organization of this data sheet easy to follow? If not, why?

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HCS360 PRODUCT IDENTIFICATION SYSTEM

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

HCS360 — _ _ /P

Package:	P =	Plastic DIP (300 mil Body), 8-lead
	SN =	Plastic SOIC (150 mil Body), 8-lead
Temperature Range:	Blank =	0°C to +70°C
	I =	–40°C to +85°C
Device:	HCS360	Code Hopping Encoder
	HCS360T	Code Hopping Encoder (Tape and Reel)

Sales and Support

Data Sheets
Products supported by a preliminary Data Sheet may have an errata sheet describing minor operational differences and recommended workarounds. To determine if an errata sheet exists for a particular device, please contact one of the following:

1. Your local Microchip sales office
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NOTES:

Microchip's Secure Data Products are covered by some or all of the following patents:
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