OVERVIEW
This document describes a PIC16C57 based code hopping automotive security system. The security system implements all the basic features found on security systems and can be changed to modify or add features as required. The code can also be moved to a higher functionality PIC® microcontroller for more I/O or code space.

FEATURES
- Code hopping alarm system
- System can handle up to six transmitters
- Learning of new transmitters
- Arm/Disarm
- Trunk release
- Car finder
- Panic
- Locking/unlocking of doors
- Door and shock sensor trigger inputs

RECOMMENDED READING
If the reader is unfamiliar with KEELOQ® Code Hopping it would be helpful to read Introduction to KEELOQ® (DS91002). This and other KEELOQ literature can be found on Microchip's Web site or from a Microchip field application engineer. The software described in this application note is available on a diskette from Microchip by ordering DS40149. A complete list of KEELOQ literature can be found at the end of the application note.
### MEMORY MAP EEPROM
(16 BIT WORDS)

<table>
<thead>
<tr>
<th>Address</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>00h</td>
<td>USER0</td>
</tr>
<tr>
<td>01h</td>
<td>LRN_PTR</td>
</tr>
<tr>
<td>02h</td>
<td>BSTATUS</td>
</tr>
<tr>
<td>03h</td>
<td>SSTATUS</td>
</tr>
<tr>
<td>04h</td>
<td>TMP/CNT</td>
</tr>
<tr>
<td>05h</td>
<td>USER1</td>
</tr>
<tr>
<td>06h</td>
<td>USER2</td>
</tr>
<tr>
<td>07h</td>
<td>USER3</td>
</tr>
<tr>
<td>08h</td>
<td>USER4</td>
</tr>
<tr>
<td>09h</td>
<td>USER5</td>
</tr>
<tr>
<td>0Ah</td>
<td>DIS0</td>
</tr>
<tr>
<td>0Bh</td>
<td>DIS1</td>
</tr>
<tr>
<td>0Ch</td>
<td>DIS2</td>
</tr>
<tr>
<td>0Dh</td>
<td>DIS3</td>
</tr>
<tr>
<td>0Eh</td>
<td>DIS4</td>
</tr>
<tr>
<td>0Fh</td>
<td>DIS5</td>
</tr>
<tr>
<td>10h</td>
<td>CNT0</td>
</tr>
<tr>
<td>11h</td>
<td>CNT1</td>
</tr>
<tr>
<td>12h</td>
<td>SER0</td>
</tr>
<tr>
<td>13h</td>
<td>SER1</td>
</tr>
<tr>
<td>14h</td>
<td>KEY0</td>
</tr>
<tr>
<td>15h</td>
<td>KEY1</td>
</tr>
<tr>
<td>16h</td>
<td>KEY2</td>
</tr>
<tr>
<td>17h</td>
<td>KEY3</td>
</tr>
<tr>
<td>18h</td>
<td>CNT10</td>
</tr>
<tr>
<td>19h</td>
<td>CNT11</td>
</tr>
<tr>
<td>1Ah</td>
<td>SER10</td>
</tr>
<tr>
<td>1Bh</td>
<td>SER11</td>
</tr>
<tr>
<td>1Ch</td>
<td>KEY10</td>
</tr>
<tr>
<td>1Dh</td>
<td>KEY11</td>
</tr>
<tr>
<td>1Eh</td>
<td>KEY12</td>
</tr>
<tr>
<td>1Fh</td>
<td>KEY13</td>
</tr>
<tr>
<td>20h</td>
<td>CNT20</td>
</tr>
<tr>
<td>21h</td>
<td>CNT21</td>
</tr>
<tr>
<td>22h</td>
<td>SER20</td>
</tr>
<tr>
<td>23h</td>
<td>SER21</td>
</tr>
<tr>
<td>24h</td>
<td>KEY20</td>
</tr>
<tr>
<td>25h</td>
<td>KEY21</td>
</tr>
<tr>
<td>26h</td>
<td>KEY22</td>
</tr>
<tr>
<td>27h</td>
<td>KEY23</td>
</tr>
<tr>
<td>28h</td>
<td>CNT30</td>
</tr>
<tr>
<td>29h</td>
<td>CNT31</td>
</tr>
<tr>
<td>2Ah</td>
<td>SER30</td>
</tr>
<tr>
<td>2Bh</td>
<td>SER31</td>
</tr>
<tr>
<td>2Ch</td>
<td>KEY30</td>
</tr>
<tr>
<td>2Dh</td>
<td>KEY31</td>
</tr>
<tr>
<td>2Eh</td>
<td>KEY32</td>
</tr>
<tr>
<td>2Fh</td>
<td>KEY33</td>
</tr>
<tr>
<td>30h</td>
<td>CNT40</td>
</tr>
<tr>
<td>31h</td>
<td>CNT41</td>
</tr>
<tr>
<td>32h</td>
<td>SER40</td>
</tr>
<tr>
<td>33h</td>
<td>SER41</td>
</tr>
<tr>
<td>34h</td>
<td>KEY40</td>
</tr>
<tr>
<td>35h</td>
<td>KEY41</td>
</tr>
<tr>
<td>36h</td>
<td>KEY42</td>
</tr>
<tr>
<td>37h</td>
<td>KEY43</td>
</tr>
<tr>
<td>38h</td>
<td>CNT50</td>
</tr>
<tr>
<td>39h</td>
<td>CNT51</td>
</tr>
<tr>
<td>3Ah</td>
<td>SER50</td>
</tr>
<tr>
<td>3Bh</td>
<td>SER51</td>
</tr>
<tr>
<td>3Ch</td>
<td>KEY50</td>
</tr>
<tr>
<td>3Dh</td>
<td>KEY51</td>
</tr>
<tr>
<td>3Eh</td>
<td>KEY52</td>
</tr>
<tr>
<td>3Fh</td>
<td>KEY53</td>
</tr>
</tbody>
</table>

**LRN_PTR** – Learn indicator points to the next available learn position.

**SSTATUS** – Stores the system status.

**BSTATUS** – Backup copy of system status.

**TMP/CNT** – Stores the temporary counter for resynchronization.
FIGURE 1: ALARM STATE DIAGRAM

- State == Alarm
- State == Immob
- State == Drive
- Remote
- 30s Time-out
- Trigger
- Remote
- Learn request
- Remote
- 30s & IGN off
- Learn complete or 30s time-out return to previous
- IGN on
- Learn request
- Learn

Reset

Armed

Drive

Immob

Alarm
OPERATION

Reset
Reset initializes the I/O ports, variables, and flags. The system status is read from EEPROM and the status is restored.

Armed
When the system enters armed state, the doors are locked (activate LOCK) and the SIREN and PLIGHT are activated for 50 ms. The LED changes to a slow flash rate. If a trigger is detected (IGN, DOOR or TRIGGER) the system changes to the alarm state.

Actions upon entry:
1. Flash parking lights for 50 ms.
2. Chirp siren for 50 ms.
3. Lock doors for 500 ms.
4. Update system status.
5. LED flash.
6. Disable start.

TABLE 1: STATE CHANGE TABLE

<table>
<thead>
<tr>
<th>Condition</th>
<th>Next State</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGN high</td>
<td>Alarm</td>
</tr>
<tr>
<td>TRIG high</td>
<td>Alarm</td>
</tr>
<tr>
<td>DOOR high</td>
<td>Alarm</td>
</tr>
<tr>
<td>Panic (any button activated for 2 seconds)</td>
<td>Alarm</td>
</tr>
<tr>
<td>Remote function 1</td>
<td>Drive</td>
</tr>
<tr>
<td>Remote function 2 (trunk release)</td>
<td>Armed</td>
</tr>
<tr>
<td>Remote function 3 (car finder)</td>
<td>Armed</td>
</tr>
<tr>
<td>LEARN high</td>
<td>Learn</td>
</tr>
</tbody>
</table>

Alarm
Alarm state is entered whenever a trigger is detected in armed state. SIREN is activated and PLIGHT is turned on and off at a 1 Hz rate. If a remote is detected in this state, the system changes to drive state. After a 30-second delay, SIREN and PLIGHT will be deactivated and the system returned to armed state.

Actions upon entry:
1. Flash parking lights.
2. Siren on.
3. LED flash.
4. Update system status.
5. Disable start.

TABLE 2: STATE CHANGE TABLE

<table>
<thead>
<tr>
<th>Condition</th>
<th>Next State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panic (any button activated for 2 seconds)</td>
<td>Alarm</td>
</tr>
<tr>
<td>Remote function 1</td>
<td>Drive</td>
</tr>
<tr>
<td>Remote function 2 (trunk release)</td>
<td>Armed</td>
</tr>
<tr>
<td>30-second timeout</td>
<td>Drive</td>
</tr>
</tbody>
</table>

Drive
When the system enters drive state, the doors are unlocked (activate UNLOCK), and the SIREN and PLIGHT are activated twice for 50 ms. The IMMOB output is activated to enable the starting of the vehicle and LED is turned off. A remote signal will return the system to armed state.

Actions upon entry:
1. Flash parking lights for 50 ms.
2. Chirp siren for 50 ms.
3. Unlock doors for 500 ms.
4. Flash parking lights for 50 ms.
5. Chirp siren for 50 ms.
6. Update system status.
7. LED off.
8. Enable start.

TABLE 3: STATE CHANGE TABLE

<table>
<thead>
<tr>
<th>Condition</th>
<th>Next State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panic (any button activated for 2 seconds)</td>
<td>Alarm</td>
</tr>
<tr>
<td>Remote function 1 &amp; IGN low</td>
<td>Armed</td>
</tr>
<tr>
<td>Remote function 1 &amp; IGN high</td>
<td>Drive</td>
</tr>
<tr>
<td>Remote function 2 (trunk release)</td>
<td>Drive</td>
</tr>
<tr>
<td>Remote function 3 (car finder)</td>
<td>Drive</td>
</tr>
<tr>
<td>30-second timeout &amp; IGN off</td>
<td>Immob</td>
</tr>
<tr>
<td>LEARN high</td>
<td>Learn</td>
</tr>
</tbody>
</table>

Immob
If the IGN is turned off for more than 30 seconds, the system will immobilize. The IMMOB output is turned off, and the LED is turned off. A remote signal only will change the state to armed, and a remote signal with the IGN on will return to drive state.

Actions upon entry:
1. Update system status.
2. LED off.
3. Disable start.

TABLE 4: STATE CHANGE TABLE

<table>
<thead>
<tr>
<th>Condition</th>
<th>Next State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panic (any button activated for 2 seconds)</td>
<td>Alarm</td>
</tr>
<tr>
<td>Remote function 1 &amp; IGN low</td>
<td>Armed</td>
</tr>
<tr>
<td>Remote function 1 &amp; IGN high</td>
<td>Drive</td>
</tr>
<tr>
<td>Remote function 2 (trunk release)</td>
<td>Immob</td>
</tr>
<tr>
<td>Remote function 3 (car finder)</td>
<td>Immob</td>
</tr>
<tr>
<td>LEARN high</td>
<td>Learn</td>
</tr>
</tbody>
</table>
Learn

A LEARN input in any state will put the system in learn mode. After learn is completed or timed out the system returns to the previous state.

Actions upon entry:
1. Update system status—set PASS1.
2. LED on.

After first transmission:
1. Update system status—set PASS2.
2. LED off.

After second transmission:
1. Update system status—set NORMAL.
2. LED on for 1 second.
3. Return to previous state.

TABLE 5: STATE CHANGE TABLE

<table>
<thead>
<tr>
<th>Condition</th>
<th>Next State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote first operation</td>
<td>Pass2</td>
</tr>
<tr>
<td>Remote second operation</td>
<td>Return to previous state</td>
</tr>
<tr>
<td>LEARN high for 8 seconds</td>
<td>Erase all transmitters</td>
</tr>
</tbody>
</table>

FUNCTIONAL MODULES

Reception

The reception routine is based on reliable algorithms used in previous implementations of KEELOQ decoders. Automatic baud rate detection is used to compensate for variations in baud rate from different encoders of a specific type as well as the difference in baud rate between different encoders (HCS200, HCS300, HCS301, HCS360, HCS361, and HCS410). The reception routine will be able to handle 56- and 66-bit transmissions. The reception routine will determine the type of transmission by the number of bits in the transmission. This routine will be the same for all implementations.

Key Generation and Decryption

Decryption is done in software in the implementation. The decryption and key generation algorithms is implemented in software. The manufacturer’s code is stored in program memory and code protected to securely store the key.

Validation

Validation consists of the following steps:
1. Checking the serial number (24 or 28 bits) against the stored transmitters.
2. Comparing the discrimination value (12 bits) against the stored discrimination value.
3. Checking that the synchronization counter falls within the first synchronization window.
4. Checking if the synchronization counter falls within the second synchronization window.
5. If found to be correct, updating the synchronization counter.

Function Interpretation

<table>
<thead>
<tr>
<th>Transmitter Button</th>
<th>Function Code</th>
<th>System Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0001</td>
<td>Arm/Disarm</td>
</tr>
<tr>
<td>2</td>
<td>0010</td>
<td>Trunk release</td>
</tr>
<tr>
<td>3</td>
<td>0011</td>
<td>Car finder</td>
</tr>
<tr>
<td>1, 2 or 3 for 2 seconds</td>
<td>00XX</td>
<td>Panic</td>
</tr>
</tbody>
</table>

Learn

The LEARN input is active high. Learning is initiated by momentarily pressing the LEARN button. The decoder uses the current learning position as a scratch pad area. This means that an unsuccessful learn will delete the information stored at that learn position. The learn indicator will not be incremented if the learn was unsuccessful. The flow chart (Figure 1) shows the learning operation.
FIGURE 2: LEARN OPERATION

1. Press Learn Button
2. LED on solid
3. Button still pressed?
   - YES
   - NO
   - Time greater than 33.6 sec.? NO
   - YES
4. First code received?
   - YES
   - NO
   - Time greater than 33.6 sec.? NO
   - YES
5. LED off
6. Time greater than 8.4 sec.?
   - YES
   - NO
7. Second code received?
   - YES
   - NO
   - Time greater than 33.6 sec.? NO
   - YES
8. Code Validated?
   - YES
   - NO
   - Learn new transmitter LED on solid for 1 second
9. LED on solid for 0.1 second
10. Exit Learn
    Turn LED off
11. END
The following checks will be performed on the received codes to determine if the transmitter is valid:

1. The first code that is received is checked for bit integrity.
2. The stored serial numbers are searched to check if a transmitter is relearned. If a relearn is taking place, that position is used. Otherwise, the position pointed to by the learn indicator will be used.
3. The serial number is stored in the current learn position and used to generate a key.
4. The hop code is decrypted and the result stored temporarily.
5. The serial number of the second code that is received will be compared to the first received serial number.
6. The second hop code is decrypted and the discrimination values compared.
7. The synchronization counters of the decrypted codes will be compared to check that they are sequential codes.
8. If all the checks pass the learn were successful, the learn indicator is incremented. Otherwise, the position is erased.

**Operation**

1. Press and release the LEARN button. Indicator LED will turn on to indicate learn mode.
2. Press transmitter button. The LED will turn off.
3. Press transmitter a second time. The LED will turn on for 1 second to indicate that the transmitter was learned successfully.
4. Repeat steps 1-3 to learn up to six transmitters. The seventh transmitter will overwrite the first transmitter that was learned.
5. Learn will be terminated if two nonsequential codes were received or if two acceptable codes were not decoded within 33.6 seconds. A valid learn will be indicated by the LED turning on solid for 1 second.
6. Erasing all the transmitters is accomplished by pressing and holding the LEARN button for 8.4 seconds. The LED will turn off at the end of the 8.4 seconds to indicate that the transmitters were erased. The learn indicator will be reset to the first position.
TABLE 6: DEVICE PINOUT

<table>
<thead>
<tr>
<th>PIN</th>
<th>PIC16C57 Function</th>
<th>Alarm Function</th>
<th>PIN</th>
<th>PIC16C57 Function</th>
<th>Alarm Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RTCC</td>
<td>APP select</td>
<td>28</td>
<td>MCLR</td>
<td>RESET</td>
</tr>
<tr>
<td>2</td>
<td>Vdd</td>
<td>+5V supply</td>
<td>27</td>
<td>Osc In</td>
<td>RC osc (4 MHz)</td>
</tr>
<tr>
<td>3</td>
<td>NC</td>
<td></td>
<td>26</td>
<td>Osc Out</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>GND</td>
<td>Ground</td>
<td>25</td>
<td>Port C Bit 7</td>
<td>NC</td>
</tr>
<tr>
<td>5</td>
<td>NC</td>
<td></td>
<td>24</td>
<td>Port C Bit 6</td>
<td>NC</td>
</tr>
<tr>
<td>6</td>
<td>Port A Bit 0</td>
<td>EEPROM DIO(3+4)</td>
<td>23</td>
<td>Port C Bit 5</td>
<td>NC</td>
</tr>
<tr>
<td>7</td>
<td>Port A Bit 1</td>
<td>EEPROM CLK (2)</td>
<td>22</td>
<td>Port C Bit 4</td>
<td>OVR</td>
</tr>
<tr>
<td>8</td>
<td>Port A Bit 2</td>
<td>EEPROM CS (1)</td>
<td>21</td>
<td>Port C Bit 3</td>
<td>LEARN</td>
</tr>
<tr>
<td>9</td>
<td>Port A Bit 3</td>
<td>RFIN</td>
<td>20</td>
<td>Port C Bit 2</td>
<td>DOOR</td>
</tr>
<tr>
<td>10</td>
<td>Port B Bit 0</td>
<td>IMMOB</td>
<td>19</td>
<td>Port C Bit 1</td>
<td>TRIG</td>
</tr>
<tr>
<td>11</td>
<td>Port B Bit 1</td>
<td>SIREN</td>
<td>18</td>
<td>Port C Bit 0</td>
<td>IGN</td>
</tr>
<tr>
<td>12</td>
<td>Port B Bit 2</td>
<td>PLIGHT</td>
<td>17</td>
<td>Port B Bit 7</td>
<td>LED</td>
</tr>
<tr>
<td>13</td>
<td>Port B Bit 3</td>
<td>NC</td>
<td>16</td>
<td>Port B Bit 6</td>
<td>TRUNK</td>
</tr>
<tr>
<td>14</td>
<td>Port B Bit 4</td>
<td>LOCK</td>
<td>15</td>
<td>Port B Bit 5</td>
<td>UNLOCK</td>
</tr>
</tbody>
</table>

TABLE 7: TIMING PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armed LED flash rate</td>
<td>1</td>
<td>per second</td>
</tr>
<tr>
<td>Siren time-out</td>
<td>33</td>
<td>second</td>
</tr>
<tr>
<td>Drive time-out</td>
<td>33</td>
<td>second</td>
</tr>
<tr>
<td>Learn time-out</td>
<td>33</td>
<td>second</td>
</tr>
<tr>
<td>All erase</td>
<td>8</td>
<td>second</td>
</tr>
<tr>
<td>LOCK, UNLOCK, TRUNK activation</td>
<td>500</td>
<td>ms</td>
</tr>
<tr>
<td>Siren chirp (arm &amp; disarm)</td>
<td>50</td>
<td>ms</td>
</tr>
<tr>
<td>Parking light (arm &amp; disarm)</td>
<td>50</td>
<td>ms</td>
</tr>
<tr>
<td>Parking light flash rate (siren)</td>
<td>1</td>
<td>per second</td>
</tr>
<tr>
<td>Panic</td>
<td>2</td>
<td>seconds</td>
</tr>
</tbody>
</table>
FIGURE 3: CIRCUIT DIAGRAM
ADDITIONAL INFORMATION

Microchip’s Secure Data Products are covered by some or all of the following:
Code hopping encoder patents issued in European countries and U.S.A.
Secure learning patents issued in European countries, U.S.A. and R.S.A.

REVISION HISTORY

Revision C (May 2011)

• Added new section Additional Information
• Minor formatting and text changes were incorporated throughout the document
Note the following details of the code protection feature on Microchip devices:

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