Texas Instruments

MicroReader MUSA Commands

Application Report

TI-RFid
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DECEMBER 2007

SCBA025 (11-08-26-009)

MicroReader MUSA Commands

Application Report

Literature Number: SCBA025 (11-08-26-009)
DECEMBER 2007

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Edition One – December 2007

This is the first edition of the **MUSA MicroReader Commands** Application Report.

It describes how to send valid commands to the Multi-Use Selectively Addressable (MUSA) LF Wedge transponder using the following products:

RI-STU-MRD1-30 (microreader)

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WARNING

A warning is used where care must be taken or a certain procedure must be followed, to prevent injury or harm to your health.

CAUTION

This indicates information on conditions that must be met or a procedure which must be followed, that if not heeded could cause permanent damage to the system.

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MUSA MicroReader Commands

ABSTRACT

With the introduction of the MUSA Wedge transponder, Texas Instruments has provided a LF transponder with increased memory, optional selective, addressing and increased security. These added benefits come at the cost of increased software complexity.

This application report explains in detail how to Read, Write, and Lock the available pages using General, Select, and Special addressing modes.

1 MUSA Memory Map

The MUSA memory map is shown in Table 1.

Table 1. MUSA Memory Map

	Lock	MSB	LSB	Page
Select Address		0xFF		1
User Data 1		0x00		2
Unique ID	√	Serial Number	MFG Code	3
User Data 2		0x0000000000		8
User Data 3		0x0000000000		9
User Data 4		0x0000000000		10
User Data 5		0x0000000000		11
User Data 6		0x0000000000		12

1.1 Memory Locations

A total of 128 bits of General memory are available. This memory (colored gray) comprises 8 bits in page 2 and a further 120 bits in pages 8, 9, and 10. This memory is Read Write (R/W) and can be irreversibly locked.

A further 80 bits of User memory is available in pages 11 and 12 (colored yellow). This is also R/W memory and can be irreversibly locked.

Page 3 contains an 8-bit manufacturing (MFG) code and a 24-bit unique ID. This page is factory locked and is Read Only (R/O).

The Select address (page 1) has a default value of 0xFF. If this value is not changed, then Read, Write, and Lock operations on Pages 2, 8, 9, and 10 can be accessed using General commands. If this location is changed to any other value, then Write and Lock operations have to be Selective addressed.

The Least Significant Byte (LSB) of Pages 11 and 12 can be read using a General Read but for all other operations the protocol must use Special Addressing

2 Protocol Overview

To use the MicroReader to send commands directly to the MUSA tag we have to use the 'RAW mode' where the actual tag command string is wrapped up in the MicroReader frame.

The MicroReader must be instructed about the length of the charge (Power burst I) and program/encrypt (Power Burst II) times and the timing values for high and low bits.

2.1 Write Page 2 Example

As an example, the complete command string to Write "22" into page 2 of a MUSA is shown below.

`0111E801320FAA004A01E001080204 0922B190 C1`

The actual MUSA command is shown in red while the MicroReader framing is shown in blue. The MicroReader framing is described in the following section.

2.1.1 The MicroReader Framing

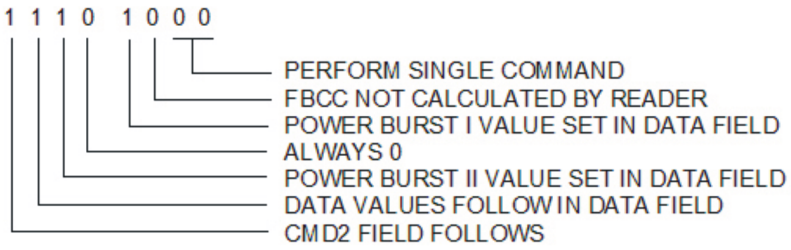
The first part of the MicroReader frame defines the length and which parameters are contained in the string:

`01 11 E8 01 320FAA004A01E0010802040922B190C1`

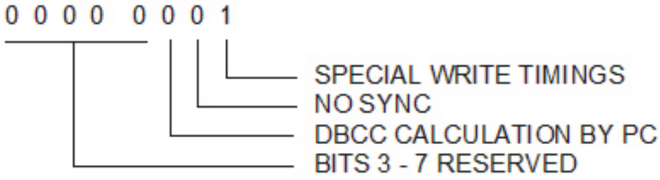
START BYTE: 01_{HEX}

LENGTH BYTE: 11_{HEX} (17 Bytes - doesn't include the start byte, itself or the LRC)

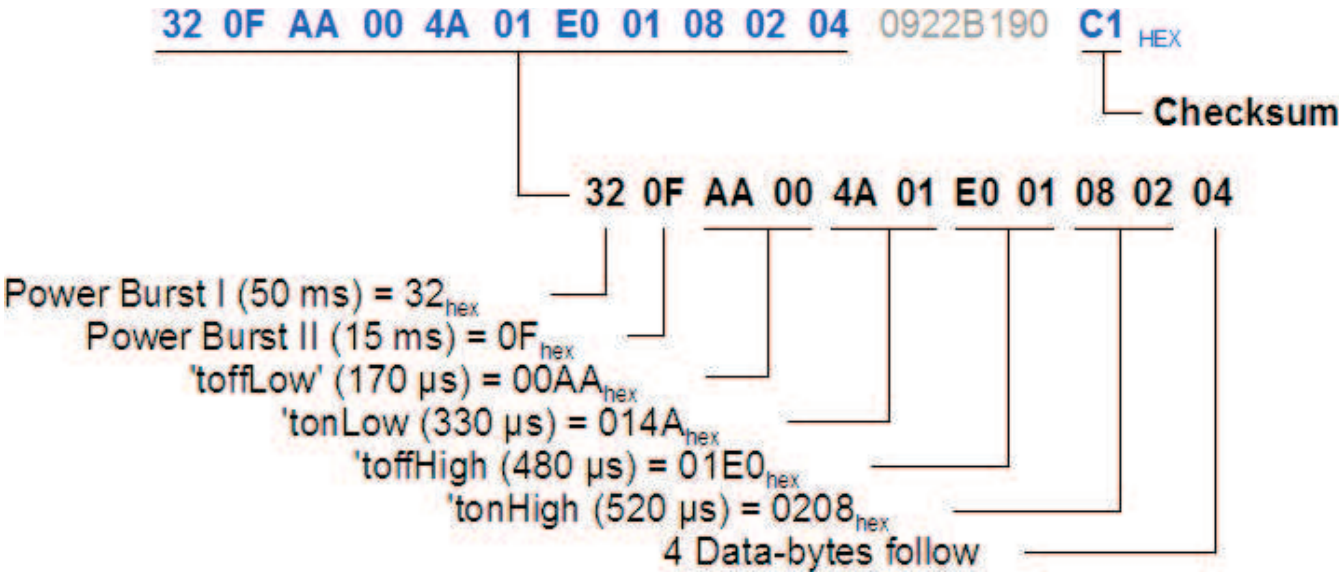
CMD1 BYTE: $E8_{HEX} = 1110\ 1000_{BIN}$



CMD2 BYTE: $01_{HEX} = 0000\ 0001_{BIN}$



The second part of the commands string sets the timing values for the power bursts and the write timings:



Note: All data is Least Significant Byte/Most Significant bit first.

The final part of the MicroReader protocol (after the MUSA data) is a Longitudinal Redundancy Checksum (LRC) that is calculated by eXclusive OR-ing (XOR) the entire string except the start byte.

2.1.2 The MUSA Command Explained

The MUSA command is explained below: Figure 1 shows the Write “22” to page 2 command structure.

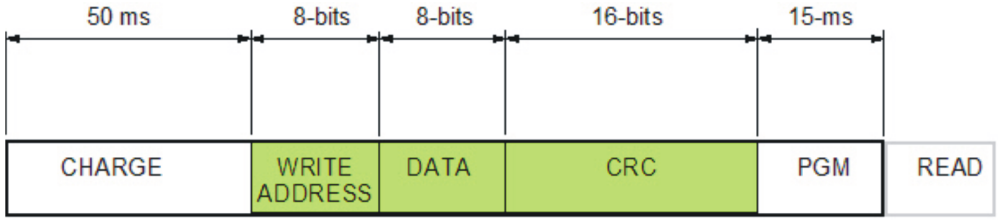
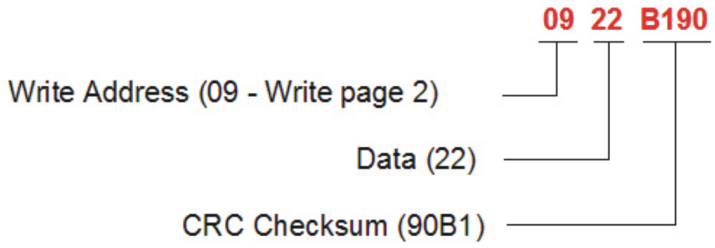


Figure 1. General Write to Page 2

The Transmitter is turned on 100% for 50 ms to power the MUSA and then the transmission is modulated to pass data to the MUSA. When all the data has been passed, the transmitter is turned on 100% again for 15 ms while the data is written to EEPROM. The tag then responds to the reader. So if we examine the MUSA command to Write “22” to page 2:

`0111E801320FAA004A01E001080204 09 22 B190 C1`



2.1.2.1 Write Address Information

The information about which action the tag is expected to execute is contained in the Write Address.

The Write addresses are given in Table 2.

Table 2. Write Address Values

OPERATION	PAGE							
	1	2	3	8	9	10	11	12
General Read	04	08	0C	20	24	28	2C	30
Write/Selective Write	05	09		21	25	29		
Lock/Selective Lock	06	0A		22	26	2A		
Selective Read	07	0B	0F	23	27	2B		
Special Addressing Write							2D	31
Special Addressing Lock							2E	32
Special Addressing Read							2F	33

From the previous example, the Write Address to Write data to page 2 is “09”.

2.1.2.2 The CCITT Checksum

The MUSA command string must have a CCITT-16 checksum calculated on the data starting with and including the Write Address. This checksum is different from other Texas Instruments’ protocols. It is defined as:

Reverse CCITT CRC-16 with initial value 0x3791

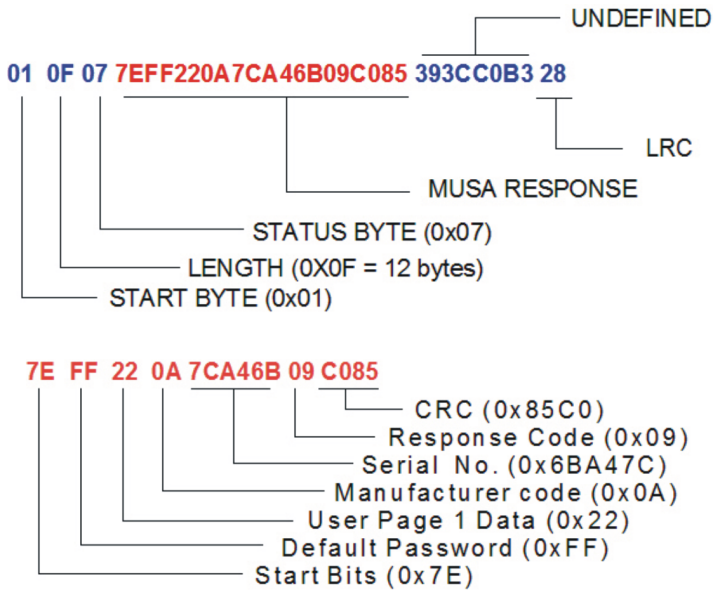
An example of Visual Basic code for this checksum is given in Appendix A.

2.2 Example Response

The following is the complete response to the Write “22” to page 2 command:

`010F07 7EFF220A7CA46B09C085 393CC0B328`

Once again the MicroReader frame is in blue and the MUSA response in red.



2.2.1 Response Code Values

If there is no tag within range of the antenna, you will receive the following response:

```
01010302
```

This is a MicroReader standard response but normally the 'health' of a response is determined from the Response Code. The response codes are detailed in Table 3.

Table 3. Response Code Values

RESPONSE CODE MEANING	PAGE							
	1	**2**	**3**	**8**	**9**	**10**	**11**	**12**
Read unlocked page	04	08		20	24	28	2C	30
Programming OK	05	09		21	25	29	2D	31
Read locked page	06	0A	0C	22	26	2A	2E	32
Read unlocked page – lock failed	00	00		00	00	00	00	00
Write complete – but Write unreliable	01	01		01	01	01	01	01
Read unlocked page – lock unreliable	02	02		02	02	02	02	02

3 Detailed Commands

The following sections describe the different groups of commands:

3.1 General Read. Pages 1, 2, 3, 8, 9, and 10

The general form of the Read command is:

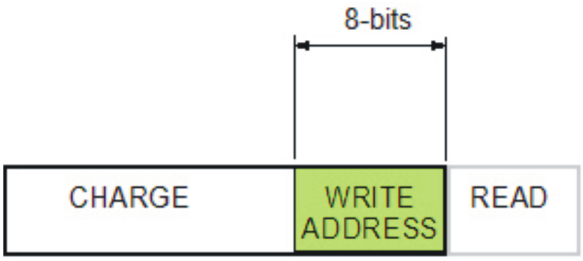


Figure 2. General Read

Typical individual command/responses are:

General Read Page 01 Command

```
>> 010DC80132AA004A01E001080201 04 F9
<< 010F077EFF220A7CA46B04255E7802204176
```

General Read Page 02 Command

```
>> 010DC80132AA004A01E001080201 08 F5
<< 010F077EFF220A7CA46B084994082A4800AD
```

General Read Page 03 Command

```
>> 010DC80132AA004A01E001080201 0C F1
<< 010F077EFF220A7CA46B0E7FF1012020089B
```

General Read Page 08 Command

```
>> 010DC80132AA004A01E001080201 20 DD
<< 010F077E220000000000203A0200C10362EC
```

General Read Page 09 Command

```
>> 010DC80132AA004A01E001080201 24 D9
<< 010F077E220000000000241E441800704002
```

General Read Page 10 Command

```
>> 010DC80132AA004A01E001080201 28 D5
<< 010F077E220000000000028728E0300C02063
```

3.2 Selective Read. Pages 1, 2, 3, 8, 9, and 10

The general form of the Selective Read command is:

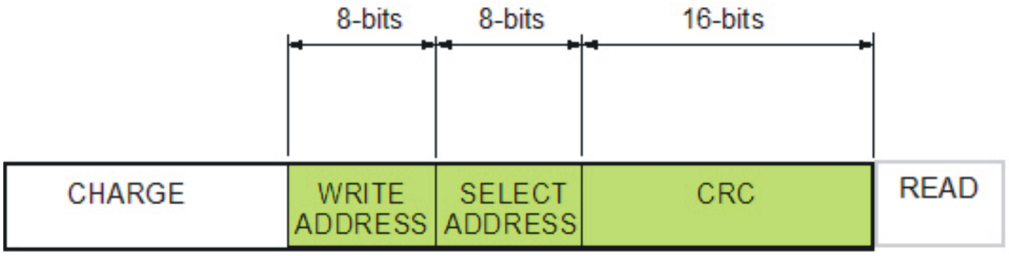


Figure 3. Selective Read

Typical individual command/responses are:

Selective Read Page 01 Command – PWD = “00”

```
>> 0110C80132AA004A01E001080204 0700B108 5B
<< 010F077E00A10A51A46B0483DD03D6098643
```

Selective Read Page 02 Command – PWD = “00”

```
>> 0110C80132AA004A01E001080204 0B0011A1 5E
<< 010F077E00A10A51A46B0AFD347A847BDEDB
```

Selective Read Page 03 Command – PWD = “00”

```
>> 0110C80132AA004A01E001080204 0F0071C6 5D
<< 010F077E00A10A51A46B0ED9728638072877
```

Selective Read Page 08 Command – PWD = “00”

```
>> 0110C80132AA004A01E001080204 2300E24C 68
<< 010F077EA188888888882240BB8CE3146F92
```

Selective Read Page 09 Command – PWD = “00”

```
>> 0110C80132AA004A01E001080204 2700822B 6B
<< 010F077EA1999999999926E18839C7108669
```

Selective Read Page 10 Command – PWD = “00”

```
>> 0110C80132AA004A01E001080204 2B002282 6E
<< 010F077EA1AAAAAAAAAA2810FFC1188423C4
```

3.3 Special Addressing Read. Pages 11 and 12

The general form of the Special Addressing Read commands is:

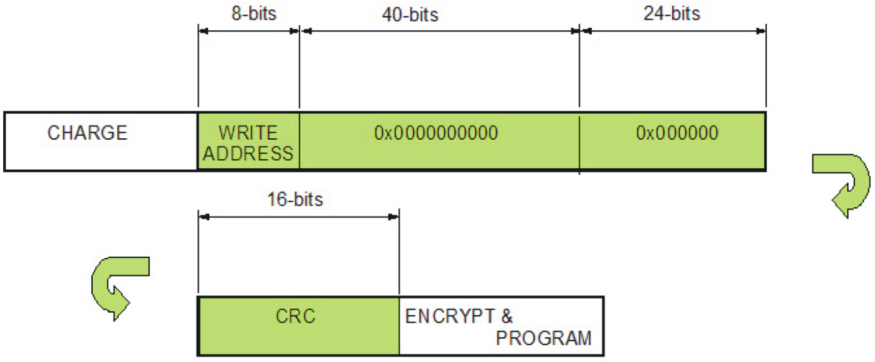


Figure 4. Special Addressing Read

Typical individual command/responses are:

Special Addressing Read of Page 11

```
>> 0118E801320FAA004A01E00108020B 2F00000000000000002966 AD
<< 010F077E22BBBBBBBBBB2CC2E2032281094A
```

Special Addressing Read of Page 12

```
>> 0118E801320FAA004A01E00108020B 330000000000000000092D9 B5
<< 010F077E22CCCCCCCCCC30A578C00CC00079
```

3.4 General Write. Pages 1 and 2

The general form of the Write format is:

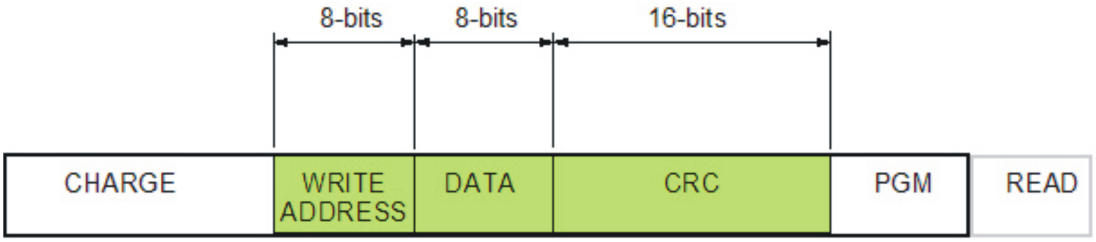


Figure 5. General Write, Pages 1 and 2

Typical individual command/responses are:

General Write Page 01 Command – Data '01'

```
>> 0112E801320FAA004A01E001080204 0501882A 6D
<< 010F077E01220A7CA46B05DC5E86010E3FDD
```

Write Page 02 Command – Data '22'

```
>> 0111E801320FAA004A01E001080204 0922B190 C1
<< 010F077EFF220A7CA46B09C08581073B7C9F
```

3.5 Selective Write. Pages 1 and 2

The general form of the Selective Write command is:

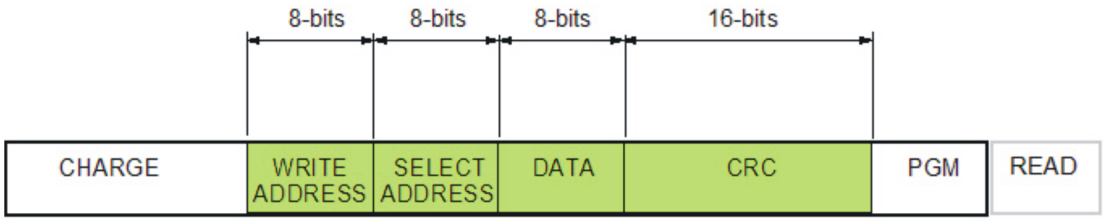


Figure 6. Selective Write, Pages 1 and 2

Note: The password in page 1 has been changed to "**00**", so selective addressing must be use.

Selective Write Page 01 Command – PWD = "00", Data "00"

```
>> 0112E801320FAA004A01E001080205 050000B211 6F
<< 010F077E00220A7CA46B0509C14020C845CD
```

Selective Write Page 02 Command – PWD = "00", Data "22"

```
>> 0112E801320FAA004A01E001080205 09002201B6 55
<< 010F077E00220A7CA46B09650B0088841791
```

3.6 General Write Pages 8, 9, and 10

The general form of the General Write Command for pages 8, 9, and 10 is:

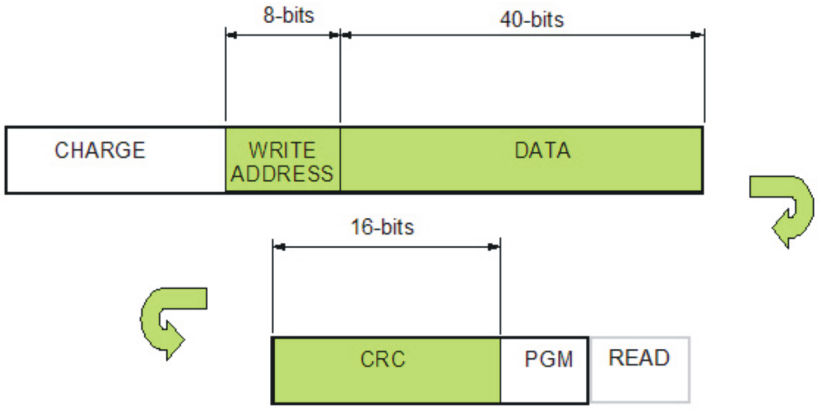


Figure 7. General Write, Pages 8 to 10

Typical individual command/responses are:

General Write Page 08 Command – Data "8888888888"

```
>> 0115E801320FAA004A01E001080208 218888888888DEBE 0A
<< 010F077E22888888888821A8A7F9BD1103A4
```

General Write Page 09 Command – Data "9999999999"

```
>> 0115E801320FAA004A01E001080208 259999999999649C 87
<< 010F077E2299999999999925099481F1EBE50B
```

General Write Page 10 Command – Data "AAAAAAAAAA"

```
>> 0115E801320FAA004A01E001080208 29AAAAAAAAAAAAFB 11
<< 010F077E22AAAAAAAAAA29EAC0FFFF3FF735
```

3.7 Selective Write Pages 8, 9, and 10

The general form of the Selective Read for pages 8 to 10 is:

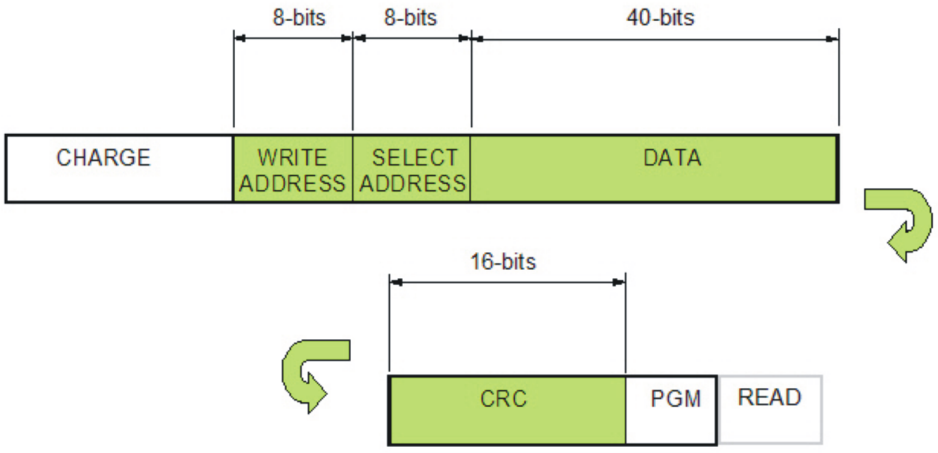


Figure 8. Selective Write, Pages 8 to 10

Typical individual command/responses are:

Selective Write Page 08 Command – PWD = “00”, Data “8888888888”

```
>> 0116E801320FAA004A01E001080209 21008888888888F713 8C
<< 010F077E22888888888821A8A702400100B1
```

Selective Write Page 09 Command – PWD = “00”, Data “9999999999”

```
>> 0116E801320FAA004A01E001080209 25009999999999974E A4
<< 010F077E2299999999992509942B371298E3
```

Selective Write Page 10 Command – PWD = “00”, Data “AAAAAAAAAA”

```
>> 0116E801320FAA004A01E001080209 2900AAAAAAAAAA37A9 DC
<< 010F077E22AAAAAAAAAA29EAC0590920018C
```

3.8 Special Addressing Write. Pages 11 and 12

The general form of the command is:

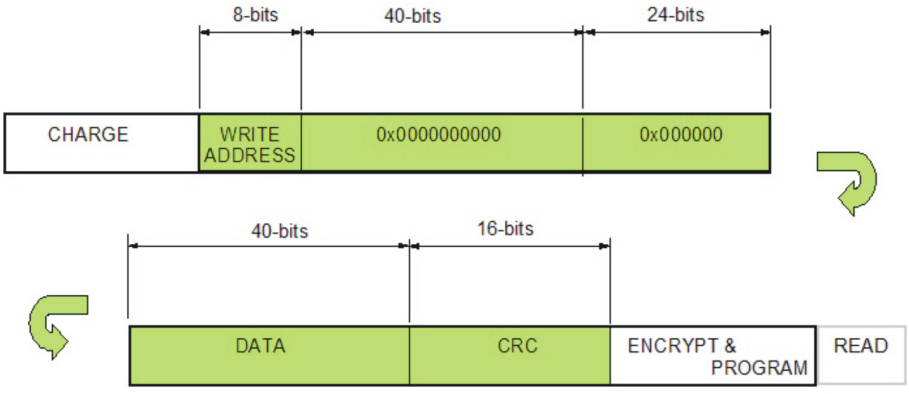


Figure 9. Special Addressing Write, Pages 11 and 12

Typical individual command/responses are:

Special Addressing Write Page 11 Command – Data “BBBBBBBBBB”

```
>> 011DE801321EAA004A01E001080210 2D0000000000000000BBBBBBBBBBC4D0 40
<< 010F077E22BBBBBBBBBB2D4BF300E0FBFF9E
```

Special Addressing Write Page 12 Command – Data “CCCCCCCCCC”

```
>> 011DE801321EAA004A01E001080210 3100000000000000000CCCCCCCCCCAB84 10
<< 010F077E22CCCCCCCCCC312C6940F3FFDE7E
```

3.9 General Lock. Pages 1, 2, 8, 9, and 10

The general form of the Lock command is:

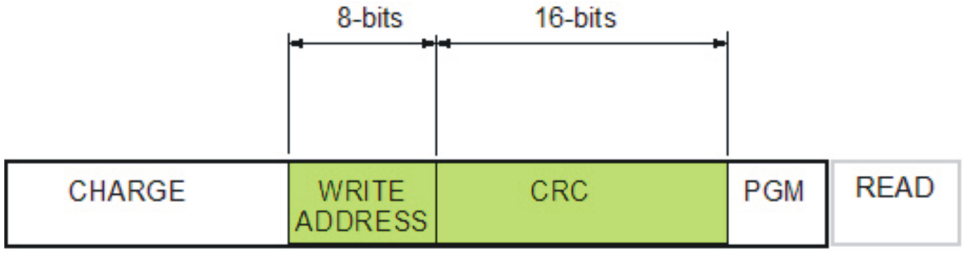


Figure 10. General Lock

Typical individual command/responses are:

General Lock Page 01 Command

```
>> 010768320F03 0601E0 B6
<< 010F077EFF220A7CA46B06377D0C000EF0AC
```

General Lock Page 02 Command

```
>> 010768320F03 0A6D2A 1C
<< 010F077EFF220A7CA46B0A5BB7F107F807FD
```

General Lock Page 08 Command

```
>> 010768320F03 222787 D3
<< 010F077E228888888888223395F101E00D45
```

General Lock Page 09 Command

```
>> 010768320F03 2603C1 B5
<< 010F077E2299999999992692A6D903FC07FE
```

General Lock Page 10 Command

```
>> 010768320F03 2A6F0B 1F
<< 010F077E22AAAAAAAAAA2A71F2031E000C46
```

3.10 Selective Lock. Pages 1, 2, 8, 9, and 10

The general form of the Selective Lock command is:

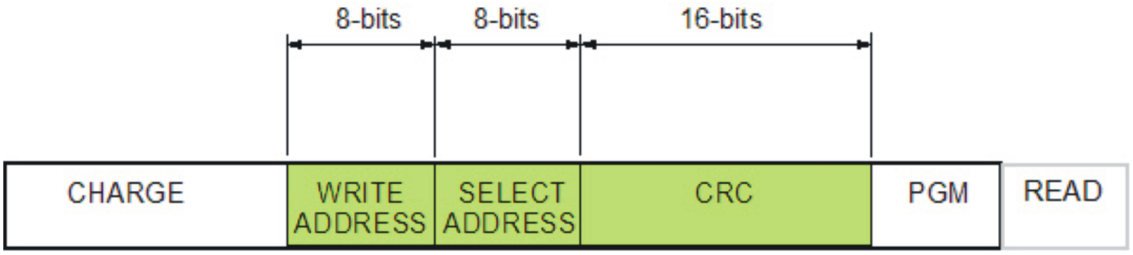


Figure 11. Selective Lock

Typical individual command/responses are:

Lock Page 01 Command – PWD = “00”

```
>> 010868320F04 06006911 27
<< 010F077E00020AE4A36B06E0F1FF372100AC
```

Lock Page 02 Command – PWD = “00”

```
>> 010868320F04 0A00C9B8 22
<< 010F077E00020AE4A36B0A8C3B00046474FB
```

Lock Page 08 Command – PWD = “00”

```
>> 010868320F04 22003A55 14
<< 010F077E02888888888822B0F6F77D000012
```

Lock Page 09 Command – PWD = “00”

```
>> 010868320F04 26005A32 17
<< 010F077E0299999999992611C5EB0A0000FE
```

Lock Page 10 Command – PWD = “00”

```
>> 010868320F04 2A00FA9B 12
<< 010F077E02AAAAAAAAAA2AF291FFDF0000B7
```

3.11 Special Addressing Lock. Pages 11 and 12

The general form of the Special Addressing Lock command is:

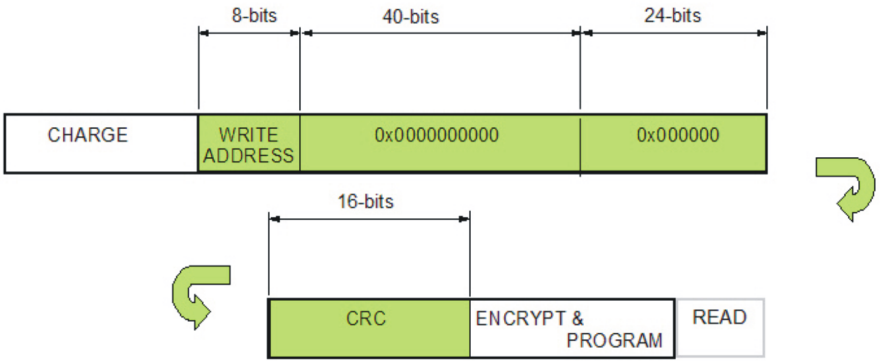


Figure 12. Special Addressing Lock

Typical individual command/responses are:

Special Addressing Lock Page 11 Command

```
>> 0118E801320FAA004A01E00108020B 2E00000000000000000D42B 1C
<< 010F077E02BBBBBBBBBB2E53A2F7FB6F0370
```

Special Addressing Lock Page 12 Command

```
>> 0118E801320FAA004A01E00108020B 32000000000000000006F94 04
<< 010F077E02CCCCCCCCCC323438D0DEC5014C
```

Appendix A CCITT Checksum Calculation

```
'*************************************************************
'*   Calculate 16-bit CCITT checksum                         *
'*                                                           *
'* The CRC has polynomial 8408,  with start value &H3791 and *
'* in a reverse direction                                    *
'*                                                           *
'* Input: Hex string  e.g.  "0922"  (must be even no. of chars) *
'* Output: 16 bit CRC  e.g.  "B190"                          *
'*                                                           *
'*************************************************************

    Function CRC16&(B$)
        Dim Power(0 To 7) As Integer
        Dim CRC As Long
        Dim I As Integer
        Dim j As Integer
        Dim ByteVal As String
        Dim TestBit As Boolean
        Dim HNibble As Byte
        Dim LNibble As Byte

        CRC = &H3791&

        For i = 0 To 7
            Power(i) = 2 ^ i
        Next i

       ' ******* convert to decimal bytes **************
        For i = 1 To Len(B$) Step 2
            If Mid$(B$, i, 1) >= "A" And Mid$(B$, i, 1) <= "F" Then
               HNibble = (Asc(Mid$(B$, i, 1)) - 55) * 16
            Else
                HNibble = (Asc(Mid$(B$, i, 1)) - 48) * 16
            End If
            If Mid$(B$, i + 1, 1) >= "A" And Mid$(B$, i + 1, 1) <= "F" Then
                LNibble = (Asc(Mid$(B$, i + 1, 1)) - 55)
            Else
                LNibble = (Asc(Mid$(B$, i + 1, 1)) - 48)
            End If
            ByteVal = (HNibble + LNibble)

          ' *******  Perform polynomial long division  *************
            For j = 0 To 7 Step 1

                TestBit = ((CRC And 1) = 1) Xor ((ByteVal And Power(j)) = Power(j))

                If TestBit = True Then
                   CRC = CRC \ 2
                   CRC = CRC Xor &H8408&
                Else
                   CRC = CRC \ 2
                End If

            Next j
        Next i

       CRC16& = CRC

    End Function
```

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