Embedded System Design Techniques™

Bootloader Design for MCUs

Session 2: Interface Protocol Design

January 26th, 2016 Jacob Beningo, CSDP



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Session Overview

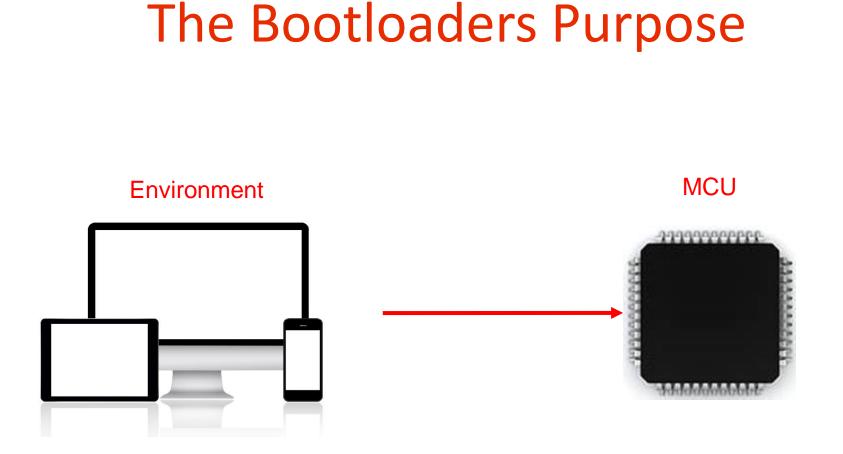
- The Bootloaders Purpose
- Application Storage Formats
- Message Packet Format
- Converting Application Formats



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All Bytes (except for the first byte and the two line termination characters) are ASCII Codes of Hexadecimal Digits i.e. they can take on the following values: '0', '1', '2', '3', '4', '5', '6', '7', '8', '9', 'A', 'B', 'C', 'D', 'E', 'F' 0x30 0x31 0x32 0x33 0x34 0x35 0x36 0x37 0x38 0x39 0x41 0x42 0x43 0x44 0x45 0x46 These characters when paired and interpreted as a hexadecimal value, display the count of remaining character pairs in the record. Values range from 0x03 (represented as '0' '3') to 0xFF (represented as 'F' 'F') Carriage Return Record Type: Line Feed '0' or '1' or '2' 13' or 15' or 17' or 18' or 19' 'S' °\r °\n' (0×00) (0x0A) (0x53) 11 Checksum type count address data or 6 or 8 Bytes to 64 Bytes These characters when paired and interpreted These characters grouped and interpreted as a hexadecimal as a hexadecimal value display the least These characters when paired and interpreted as significant byte of the ones complement of the value, display the address at which the data field is to be loaded into memory. The length of the field depends on the hexadecimal values represent the memory loadable sum of the byte values represented by the pairs data or descriptive information. of characters making up the count, the address, number of bytes necessary to hold the address. A 2-byte and the data fields address uses 4 characters, a 3-byte address uses 6

https://en.wikipedia.org/wiki/SREC_(file_format)#/media/File:Motorola_SREC_Chart.png

characters, and a 4-byte address uses 8 characters.

Motorola S-record format ready reckoner

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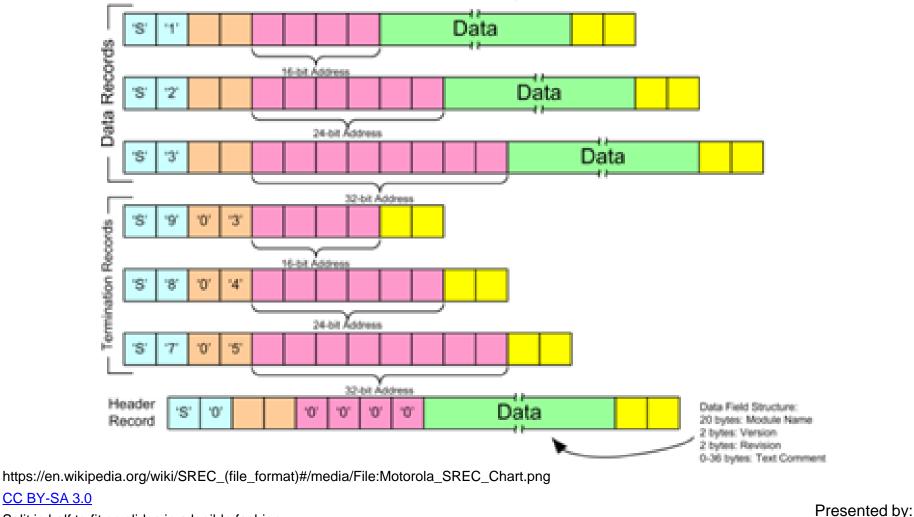
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Diagrams based on data presented at:

http://www.amelek.gda.pl/avr/uisp/srecord.htm

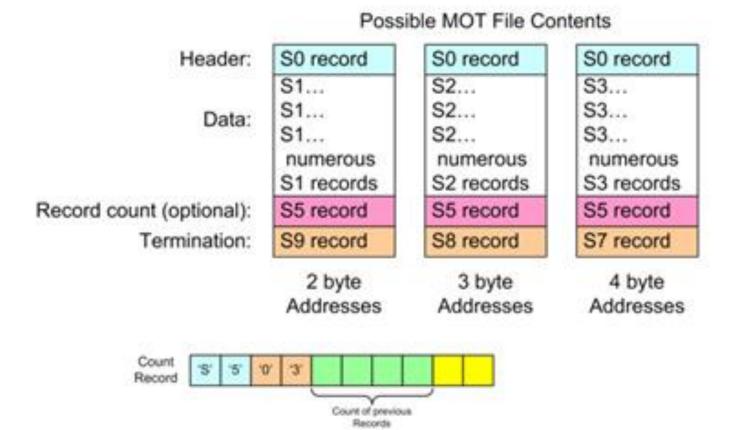


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- 1 S00600004844521B
- 2 \$32500420000500D0120C5014200CD014200CF014200AD084200210342007D0C42000000000008
- 4 S5030346B3
- 5 S70500420000B8



General Message Format

Start Message	OPCODE	Data Length	Data	Checksum
(8 bits)	(8 bits)	(8 bits)	(x bytes)	(16 bits)

Checksum

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- Fletcher16 (Approaches error detection of CRC)
- https://en.wikipedia.org/wiki/Fletcher%27s_check sum



```
uint16 t Packet ChecksumCalculate(uint8 t const * Data, uint16 t Bytes)
Ł
  uint16 t sum1 = 0xff, sum2 = 0xff;
  uint16 t tlen;
  while (Bytes)
  {
    tlen = Bytes > 20 ? 20 : Bytes;
    Bytes -= tlen;
    do{
      sum2 += sum1 += *Data++;
    } while (--tlen);
    sum1 = (sum1 \& 0xff) + (sum1 >> 8);
    sum2 = (sum2 \& 0xff) + (sum2 >> 8);
  }
  // Second reduction step to reduce sums to 8 bits
  sum1 = (sum1 & 0xff) + (sum1 >> 8);
  sum2 = (sum2 \& 0xff) + (sum2 >> 8);
  return (sum2 << 8 | sum1);</pre>
}
```

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OPCODE	Command	Description
0x30	Bootloader Enter	This command is used to put the system into boot-loader mode.
0x31	Bootloader Exit	Used to exit the bootloader with the intention of entering the application code.
0x32	Device Erase	Erases the application buffer space and prepares for receipt of new application code.
0x33	Device Program	S-Record to program to the application buffer space.
0x34	Device Secure	Secures the flash space from being read and written
0x35	Device Unsecure	Unsecure the flash space for writing and reading.
0x36	Query Device	Used to determine if the system is in bootloader or application mode.
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Message Format

```
45 白/**
   * Defines the commands being received by the bootloader.
46
47 -*/
48
   typedef enum
49 - {
    BOOT ENABLE = 0 \times 30,
                             /**< Enter bootloader */
50
   BOOT EXIT = 0x31,
51
                              /**< Exit bootloader */
   ERASE DEVICE = 0x32, /**< Erase application area of memory */
52
53 PROGRAM DEVICE = 0x33, /**< Program device with an s-record */
   QUERY_DEVICE = 0x34, /**< Set the Slave Tx buffer with the current state */
54
    COPY APPLICATION = 0x35, /** Copy application from buffer to app space */
55
56
57
     END OF COMMANDS /**< End of command list */
58
    }BootCommand t;
59
60 白 / * *
    * Defines the responses sent by the bootloader.
61
62 -*/
    typedef enum
63
64 🗐 {
    IDLE = 0x00, /**< Bootloader is idle */</pre>
65
   ERASE FINISHED = 0x01, /**< Erase finished */
66
67 WRITE FINISHED = 0x02, /**< Write finished */
    CHECKSUM FAIL = 0x03, /**< Checksum error */
68
    BUSY = 0x04,
                   /**< Bootloader busy */
69
    COPY FINISHED = 0x05, /**< Copy Completed */
70
71
    RECORD APP SPACE INVALID = 0 \times 10,
72
     PACKET INVALID = 0 \times 20,
73
                          /**< Application running */
74
     APP MODE = 0 \times 01,
      BOOT MODE = 0 \times 03
                         /**< Bootloader running */
75
    }BootResponse t;
76
```

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- Best Practices
 - Use a packet format
 - Use a checksum or CRC
 - Track record packet numbers
 - Use ACK and NAK for each packet
 - Create specific error codes
 - Don't assume that errors rarely happen
 - Use 32 bit addressing as a default
 - Include response timeout



Some IDEs only put out one record format!

Useful format converter

- Hex2bin (<u>http://hex2bin.sourceforge.net/)</u>
- Bin2Srec (<u>http://www.s-record.com/</u>)
- Many other tools

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🔝 Ob	tions for Target 'Target 1	1'	\times
Devi	ce Target Output Listin	ting User C/C++ Asm Linker Debug Utilities	_
	Select Folder for Objects	Name of Executable: MZM_Firmware	
	Create Executable: .\0 Image: Debug Information	Objects\MZM_Firmware Check this box! Create Batch File	
	Create HEX File Frowse Information		
	Create Library: .\Objec	cts\MZM_Firmware.lib	
		OK Cancel Defaults Help	
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• Hex2bin

hex2bin filename

```
F:\>hex2bin MZM_Firmware.hex
hex2bin v2.1, Copyright (C) 2015 Jacques Pelletier & contributors
Lowest address: 4194304
Highest address: 4219631
Starting address: 4194304
Max Length: 25328
Binary file start = 00400000
Records start = 00400000
Highest address = 004062EF
Pad Byte = FF
F:\>
```

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- Bin2Srec
 - Bin2srec –a 4 –o 0x420000 input_filename > output_filename

F:\>bin2srec -a 4 MZM_Firmware.bin > MZM_Firmware.srec
BIN2SREC 1.46 - Convert binary to Motorola S-Record file. Copyright (c) 2000-2015 Ant Goffart - http://www.s-record.com/
Input binary file: MZM_Firmware.bin Begin address = 0h
End address = 62EFh Address offset = 0h
Maximum address = 62EFh Address bytes = 4
Processing complete
F:\>bin2srec -a 4 MZM_Firmware.bin > MZM_Firmware.srec

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Additional Resources

- Download Course Material for
 - Updated C Doxygen Templates (Sept 2015)
 - Example source code
 - Bootloader White Paper
 - Templates
- Microcontroller API Standard
- EDN Embedded Basics Articles
- Embedded Bytes Newsletter



From <u>www.beningo.com</u> under

Blog and Articles > Software Techniques > CEC Bootloader
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http://bit.ly/1BAHYXm

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