AN716: Instructions for Using Image-Builder

Image-builder is Silicon Labs' tool for creating Zigbee over-the-air (OTA) bootloader files for use with all Silicon Labs EFR32MGx platforms. It takes one or more files and wraps them in the file format as declared in the Zigbee specification. This application note provides complete instructions for creating OTA files using Image-builder.

KEY POINTS

- Displaying OTA files
- Creating an OTA file
- Extracting tags from an OTA file

1. Overview

Image-builder is Silicon Labs' tool for creating Zigbee over-the-air (OTA) bootloader files. It takes one or more files and wraps them in the file format,as declared in the Zigbee specification. The files it wraps are normally bootloader files (such as GBL).

Image-builder comes in two versions: one with Elliptical Curve Cryptography (ECC) and one without ECC. Due to U.S. export regulations, the version with ECC may not be distributed to certain countries. Silicon Labs distributes the version without ECC with the normal stack releases, but only distributes the version with ECC through the Silicon Labs ZigBee support portal. The non-ECC version of the tool can do everything that the ECC version can, except creating and verifying ECDSA signatures.

For more information about Zigbee over-the-air please see the Over-the-Air Upgrade Plugins section in *UG391: Zigbee Application Framework Developer's Guide*, provided with the EmberZNet stack release.

2. Help

Running Image-builder without arguments produces the program's command line interface syntax.

```
image-builder Copyright 2013 Silicon Laboratories, Inc.
Version: 1.5.1
ECC signature support present.

Usage: image-builder <operation> [ <additional arguments> ]

Print operation: Arguments for printing OTA header information
  -p, --print=<filename|directory> print either (1) the OTA header of the specified file, or (2) all OTA files
found in the directory.

Create operation: Arguments for creating OTA files
  -c, --create=<filename>        create OTA file
  -v, --version=<4-bytes-hex>    firmware version
  -m, --manuf-id=<2-bytes-hex>   manufacturer ID
  -i, --image-type=<2-bytes-hex> image type ID
  -s, --stack-version=<2-bytes>  zigbee stack version (optional)
  --string=<text>                header string text (optional)
  --min-hw-ver=<2-bytes-hex>     Minimum hardware version (optional)
  --max-hw-ver=<2-bytes-hex>     Maximum hardware version (optional)
  --upgrade-dest=<8-bytes-hex-big-endian> The EUI64 of the device the file is intended for (optional)
  -t, --tag-id=<2-bytes-hex>     tag identifier
  -l, --tag-length=<32-bit length> length of dummy data for tag
  -f, --tag-file=<filepath>      file to include or extract as data with associated tag
  --security-credentials=<1-byte-hex> The security credentials required for this upgrade.
  --test-sign=<crypto-suite-number> Sign the image with the built-in security key
  --sign=<filename>              Sign using certificate and private key from file (or stdin)

Extract operation: Extract tags from an OTA file
  -x, --extract=<filename>       Extract tags from the specified OTA file
  -t, --tag-id=<2-bytes-hex>     tag identifier
  -f, --tag-file=<filepath>      file to include or extract as data with associated tag

EBL operation: Arguments for manipulating EBLs
  --ebl-print=<filename>         Print the contents of an EBL

Help operation
  -h, --help                     display this usage and exit
  --help-signing                 Print syntax for signing certificate files
```

3. Displaying OTA Files

You can see the contents of OTA files by using the `-p` command-line option. An example of the contents of an OTA file is shown below.

```
bash$ ./image-builder-ecc -p app/framework/plugin/ota-storage-simple-ram/ota-static-sample.ota
image-builder (C) 2013 by Silicon Labs
Version: 1.4.1
ECC signature support present.
File: app/framework/plugin/ota-storage-simple-ram/ota-static-sample.ota
Magic Number:         0x0BEEF11E
Header Version:       0x0100
Header Length:        56 bytes
Field Control:        0x0000
Manufacturer ID:      0x1002
Image Type:           0x5678
Firmware Version:     0x00000005
Stack Version:        0x0002
Header String:        The latest and greatest upgrade.
Total Image Size:     182 bytes
Total Tags:           3
  ID:                 0xF000   (Manufacturer Specific)
  Length:             10 bytes
  ID:                 0x0002   (ECDSA Signing Certificate)
  Length:             48 bytes
    Subject: (>)000D6F0000198B36
    Issuer:  (>)5445535453454341 (Certicom TEST CA)
  ID:                 0x0001   (ECDSA Signature)
  Length:             50 bytes
    Signer:  (>)000D6F0000198B36
     Data:      01C2C31CB8C40064  EABB3189AD8969EA
                C25893183A023BD2  8D5FB2134D3E07B9
                2E06A258E478D20C  7ACC
Using Certicom TEST CA issued certificate.
Message Digest: E26A886E8030458DA084586F2DCB08A2
Signature is valid
Found 1 files.
```

4. Creating an OTA File

To create an OTA file you need to first decide the parameters of the firmware image that will be embedded in the OTA file.

The basic build parameters are `Manufacturer ID`, `Image Type Id`, and `Version`. Together these form a unique identifier to denote the image for all OTA servers that serve up the file to clients.

4.1 Manufacturer ID

The manufacturer ID is the Zigbee-assigned value that is unique to the manufacturer. For example, the Silicon Labs manufacturer ID is 0x1049. Manufacturers must contact the Zigbee Alliance to obtain their own manufacturer ID.

4.2 Image Type ID

The image type ID is an identifier to indicate the specific product group to which the update applies. For example, if your company manufactures light switches and thermostats, which required different flavors of software, you would use different image type IDs to indicate whether the upgrade is for a light switch or a thermostat.

Zigbee has specified a few values, but the rest (0x0000-0xFFBF) are open to each manufacturer's interpretation. The manufacturer-specific values for the image type are unique to each manufacturer ID. Therefore different vendors may use the same image type ID within the manufacturer-specific range without a conflict. The image type ID values are shown in the following table.

Table 4.1. Image Type ID Values

Image Type ID	Description
0x0000 – 0xffbf	Manufacturer Specific
0xffc0	Security credential
0xffc1	Configuration
0xffc2	Log
0xffc3 – 0xfffe	Reserved (unassigned)
0xffff	Reserved: wild card

4.3 Version

The Version is the software version that is associated with the file or files that are wrapped in the OTA package. This version is used by the OTA cluster to query when a new software update is ready. In general it is recommended that this be an increasing number for each new software version. However, you are free to use whatever scheme you would like. For example, our version number is encoded as hexadecimal digits, so version 4.2.0 build 1 would be 0x00004201.

4.4 Tags

Tags are blobs of data inside the OTA file that are interpreted by the device receiving and processing the update. A few tags are defined and global to all devices, such as the ECDSA Signature Tag and the ECDSA Signer Certificate tag. However, tags can be manufacturer-specific and contain information only pertinent to certain devices that know how to handle them. Each tag is labeled with an identification number. The list of identification numbers is specified by the OTA cluster, as shown in the following table.

Table 4.2. Tag Identifiers

Identification Number	Description
0x0000	Upgrade Image
0x0001	ECDSA Signature
0x0002	ECDSA Signing Certificate
0x0003	Image Integrity Code
0x0004	Picture Data
0x0005	ECDSA 283K1 Signature
0x0006	ECDSA 283K1 Signing Certificate
0x0007 – 0xefff	Reserved by Zigbee
0xf000 – 0xffff	Manufacturer Specific Use

An OTA file should have at least one tag containing data that is of use to the client receiving the file. There is no limit to the maximum number of tags in the file. The main upgrade file (such as the GBL file) is normally specified as tag 0x0000 (upgrade file), but this is not required by the specification. The OTA cluster code looks for this tag when passing this data to the bootloader of the device.

A NULL upgrade file is used for many of the Zigbee over-the-air bootload cluster certification tests. This is a small file that contains no upgrade code and will not be passed to the bootloader. However the OTA cluster code will download and process it. These files should be specified with a tag OTHER than 0x0000 (upgrade image) inside of them. They may in fact contain no tags and the OTA client code will not process them. Instructions for creating a NULL upgrade file are provided in the section 4.7 Special OTA Files.

4.5 String

The OTA header string is a human readable string that indicates what the upgrade file is and who it is for. This string is not used by the OTA cluster code and it is only for display purposes.

4.6 Signing

The Zigbee Smart Energy Profile requires that OTA files be signed by the manufacturer. Downloaded files must be validated by the OTA client prior to installation. When images are signed the signer's certificate is included automatically as a tag in the file, and a signature tag is added as the last tag in the file.

Files can be signed in two ways: using a built-in test certificate and using a user-supplied certificate.

4.6.1 Built-in Test Certificate

Image-builder contains a built-in test certificate that can be used to sign images with the --test-sign option. This certificate is not intended for production use. It is provided as a sample to allow signing and verification to be done in development environments. This built-in certificate used by the tool is automatically accepted by the default Simplicity Studio AppBuilder configuration for the plugin OTA Client.

Note: Silicon Labs strongly recommends that manufacturers do NOT use the built-in test certificate to generate production images to be shipped to deployed, production device. See 4.6.2 User-Supplied Certificates below.

Production signer certificates must be handled differently than test certificates. For more information on this topic please see the Over-the-Air Upgrade Plugins section in Chapter 15 of document in *UG391: Zigbee Application Framework Developer's Guide*, provided with the EmberZNet PRO stack release.

Example Using the Built-in Test Certificate

The following is an example of creating an OTA file and signing using the built-in test certificate.

```
bash$   ./image-builder-ecc  --create  test.ota  --manuf-id  0x1002  --image-type  0x5678  --version  0x00000005  --
string "EFR32 uart fifo ecc tokens" --tag-id 0x0000 --tag-file uart-fifo-ecc-tokens.gbl --test-sign
image-builder (C) 2013 by Silicon Labs
Version: 1.4.1
ECC signature support present.
WARNING: Using internal test key and certificate.
WARNING: Using weak random number generator. Use '--sign' for more secure generator.
File: test.ota
Magic Number:         0x0BEEF11E
Header Version:       0x0100
Header Length:        56 bytes
Field Control:        0x0000
Manufacturer ID:      0x1002
Image Type:           0x5678
Firmware Version:     0x00000005
Stack Version:        0x0002
Header String:        EFR32 uart fifo ecc tokens
Total Image Size:     112044 bytes
Total Tags:           3
  ID:                 0x0000   (Upgrade Image)
  Length:             111872 bytes
  ID:                 0x0002   (ECDSA Signing Certificate)
  Length:             48 bytes
    Subject: (>)000D6F0000198B36
    Issuer:  (>)5445535453454341 (Certicom TEST CA)
  ID:                 0x0001   (ECDSA Signature)
  Length:             50 bytes
    Signer:  (>)000D6F0000198B36
     Data:      03ECE34CF26E86E3  7EE3A313A7D9D2ED
                3C01FA1230029AF9  8523BD2759CB1E7F
                41D045109AAABDDB  A338
Using Certicom TEST CA issued certificate.
Message Digest: 77CA8B210A9AAE225CCA7736AFABE0A8
Signature is valid
```

4.6.2 User-Supplied Certificates

Image-builder also allows users to supply their own certificates to sign their OTA files with the `--sign <filename>` option. The certificate can be either 163k1 or 283k1. The certificates may either be test certificates issued from the Certicom Test CA, or production certificates issued from the Certicom Production CA. For details about obtaining and modifying a test certificate from Certicom, see document *AN714: Smart Energy ECC-Enabled Device Setup Process*.

Note: Silicon Labs strongly recommends that manufactures use their own certificates issued from the Certicom Production CA to sign production images to be shipped to deployed, production devices.

The user-supplied certificates may either be supplied from a text file on disk, or through the command-line STDIN. To provide the data using STDIN, use the `--sign` option with the special filename stdin. The program reads data from STDIN, expecting the same format as a file on disk. The format for both the file on disk and STDIN is as follows:

```
# Comment lines begin with a '#' and are ignored
Certificate: <48-byte hexadecimal array>
Private Key: <21-byte hexadecimal array>
```

Alternatively, the certificate files supported by Simplicity Commander are also accepted, as follows:

```
Device Implicit Cert: <48-byte hex array>
Device Private Key: <21-byte hex array>
# These two parameters are ignored, as they are not used by the image-builder tool.
CA Public Key: <22-byte hex array>
Device Public key: <22-byte hex array>
```

Note: Array data must be specified on the same continuous line, with a carriage return only at the end.

Image-builder reads the data from the text file (or stdin), parses the values to make sure they are formatted correctly, and then uses the data to sign the image. Below is an example of a text file with a user-supplied certificate.

```
Certificate:0307834a5cfa185ee9c9550a6561212af7082ef6d319000d6f000092e04e5445535453454341000000000000000000000000
Private Key:02032ed11b3ceeddae99ce00e23bc54564d16b18ea
```

Example Using User-Supplied Certificates

The following is an example of creating an OTA file and signing using a user-supplied certificate.

```
$ ./image-builder-ecc --create test.ota --manuf-id 0x1002 --image-type 0x5678 --version 0x00000005 --string
"EFR32 uart fifo ecc tokens" --tag-id 0x0000 --tag-file uart-fifo-ecc-tokens.gbl --sign user-supplied-cert.txt
image-builder (C) 2013 by Silicon Labs
Version: 1.4.1
ECC signature support present.
Using user supplied key and certificate.
Using Certicom TEST CA issued certificate.
Using /dev/random for random number generation
Gathing sufficient entropy... (may take up to a minute)...
File: test.ota
Magic Number:         0x0BEEF11E
Header Version:       0x0100
Header Length:        56 bytes
Field Control:        0x0000
Manufacturer ID:      0x1002
Image Type:           0x5678
Firmware Version:     0x00000005
Stack Version:        0x0002
Header String:        EFR32 uart fifo ecc tokens
Total Image Size:     112044 bytes
Total Tags:           3
  ID:                 0x0000   (Upgrade Image)
  Length:             111872 bytes
  ID:                 0x0002   (ECDSA Signing Certificate)
  Length:             48 bytes
    Subject: (>)000D6F000092E04E
    Issuer:  (>)5445535453454341 (Certicom TEST CA)
  ID:                 0x0001   (ECDSA Signature)
  Length:             50 bytes
    Signer:  (>)000D6F000092E04E
```

```
     Data:      03E9F2CE826C4CB9  B734BBA2933F1F27
                3485DDE831030C78  F214589E1C46EB9D
                7C50C3FFA300D4C1  8C40
Using Certicom TEST CA issued certificate.
Message Digest: 040797A3C2BC13BC04D1B5C661E4D877
Signature is valid
```

4.6.3 AppBuilder Integration

In order for the device to accept an image signed using a user-supplied certificate, the EUI64 of that signer must be specified to the OTA client plugin. On the AppBuilder Plugins tab, select the OTA Bootload Cluster Client plugin. If the plugin is not enabled, on the ZCL Clusters tab, find the Over-the-Air Bootloading cluster and check Client.

In the OTA Bootload Cluster Client plugin, under the Options, change the Image Signer EUI64 0 value to the EUI64 of the primary signer, as shown in the following figure. If other EUI64s are used for signing, then change Image Signer EUI64 1 and Image Signer EUI64 2 to reflect the values of the other two signers' EUI64s.

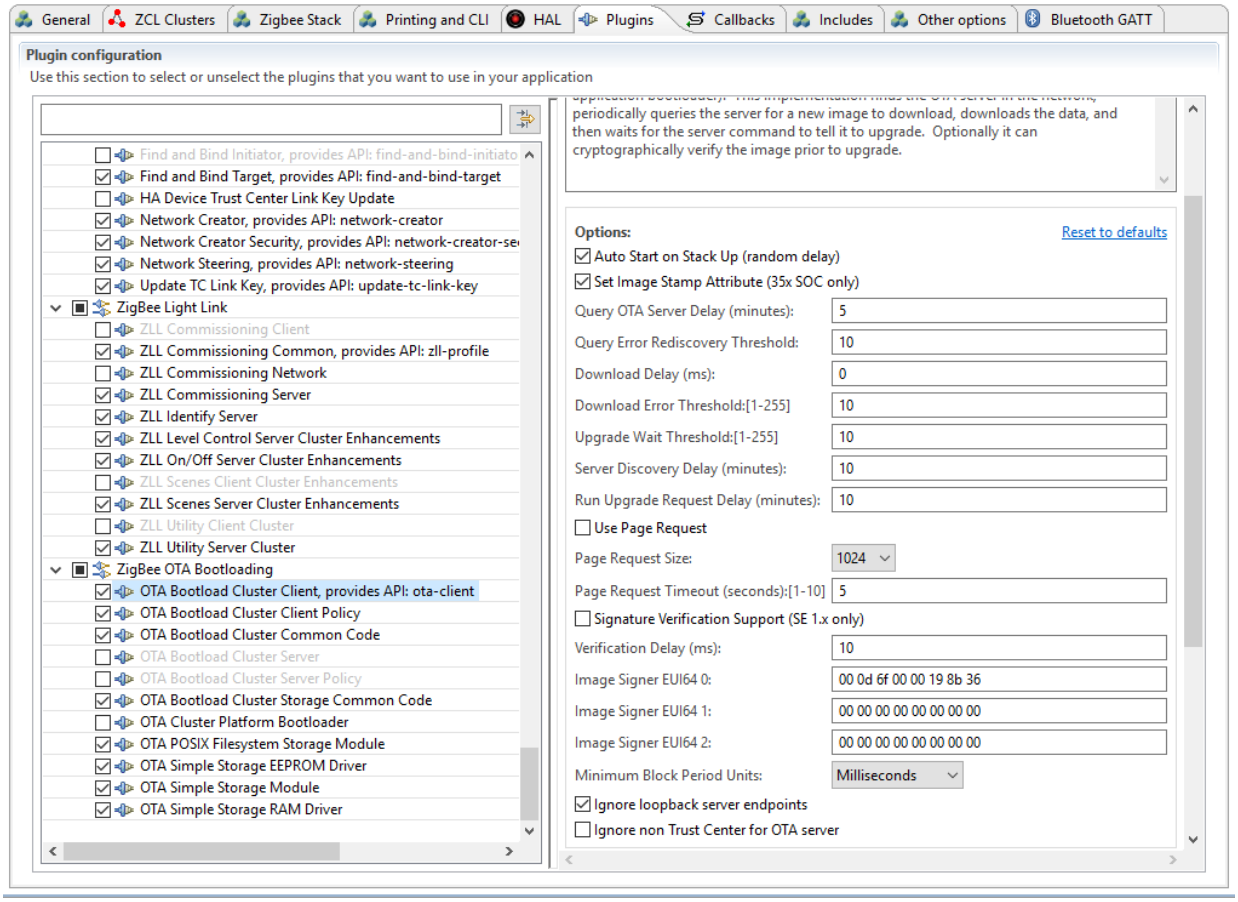


Figure 4.1. AppBuilder Plugins Interface Example

By default, AppBuilder uses the EUI64 of the built-in test certificate for Image Signer EUI64 0.

4.7 Special OTA Files

This section details certain configurations that apply to various special OTA files.

4.7.1 Null OTA Files

The certification process for the Zigbee Over-the-Air Bootload cluster client requires that the manufacturer provides a NULL upgrade file to the test house for testing. A NULL OTA upgrade file does not contain an actual upgrade image inside it (such as a GBL). It is much smaller than a full upgrade image, but otherwise the same as a normal Zigbee OTA file. Some of the certification tests performed by the test house use the NULL file as a way of speeding up the testing process.

NULL upgrade files can be created using Image-builder with the `--tag-length` option instead of the `--tag-file` option. The value passed to `--tag-length` is usually something small, such as 10. This option generates a sequence of bytes incrementing from 0 based on the length passed in. When creating the files, you should provide a tag ID other than 0x0000, which Zigbee has defined as “Upgrade Image”. This step prevents confusion between a real upgrade file and a NULL upgrade file. If both files have the same tag ID it is difficult to tell them apart. However, the Gecko Bootloader will never try to bootload a NULL upgrade file. It always verifies that the data is a valid GBL file before bootloading it.

NULL files can optionally be signed in the same way as regular OTA files. If the signature is present the OTA Client Policy plugin software will verify it before examining the contents to see if the file contains a NULL image.

Here is an example of how to create a NULL OTA file:

```
$ ./image-builder --create null-file.ota --version 0x00000005 --manuf-id 0x1002 --image-type 0x5678 --string
"NULL upgrade file" --tag-id 0xfffff --tag-length 10
image-builder (C) 2013 by Silicon Labs
Version: 1.4.1
ECC signature support NOT present.
File: null-file.ota
Magic Number:         0x0BEEF11E
Header Version:       0x0100
Header Length:        56 bytes
Field Control:        0x0000
Manufacturer ID:      0x1002
Image Type:           0x5678
Firmware Version:     0x00000005
Stack Version:        0x0002
Header String:        NULL upgrade file
Total Image Size:     72 bytes
Total Tags:           1
  ID:                 0xFFFF   (Manufacturer Specific)
  Length:             10 bytes
```

5. Extracting Tags from an OTA File

In some cases it may be helpful to extract data from specific tags of an existing OTA file. This can be done with the `--extract` command-line option.

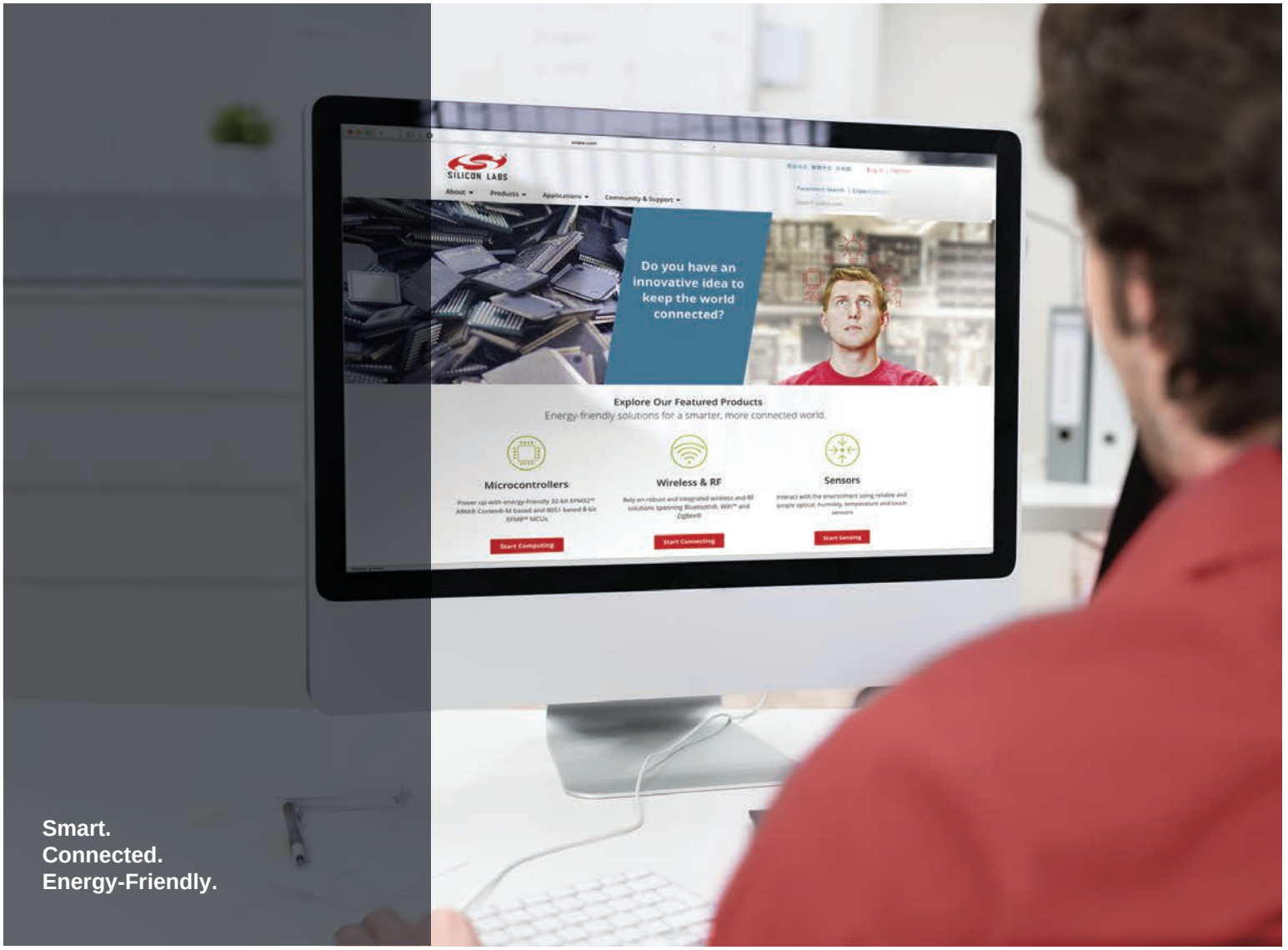
For each tag you would like to extract data from you must specify a `--tag-id`, and the `--tag-file` option that corresponds to the output file.

In the following example, the existing OTA file is shown first, and then the tag extraction.

```
bash$ ./image-builder -p test.ota
image-builder (C) 2013 by Silicon Labs
Version: 1.4.1
ECC signature support NOT present.
File: test.ota
Magic Number:         0x0BEEF11E
Header Version:       0x0100
Header Length:        56 bytes
Field Control:        0x0000
Manufacturer ID:      0x0001
Image Type:           0x0001
Firmware Version:     0x00000001
Stack Version:        0x0002
Header String:        test extraction image
Total Image Size:     214 bytes
Total Tags:           3
  ID:                 0xFFF0   (Manufacturer Specific)
  Length:             10 bytes
  ID:                 0xFFFE   (Manufacturer Specific)
  Length:             30 bytes
  ID:                 0xF000   (Manufacturer Specific)
  Length:             100 bytes
Found 1 files.
```

You can extract all of the tags by specifying each tag and the associated file output. For example:

```
bash$ ./image-builder-ecc -x test.ota -t 0xfff0 -f tag-fff0.txt -t 0xfffe -f tag-fffe.txt -t 0xf000 -f tag-
f000.txt
image-builder (C) 2013 by Silicon Labs
Version: 1.4.1
ECC signature support present.
Wrote tag 0xFFF0, length 10 bytes, to file 'tag-fff0.txt'
Wrote tag 0xFFFE, length 30 bytes, to file 'tag-fffe.txt'
Wrote tag 0xF000, length 100 bytes, to file 'tag-f000.txt'
```



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