



# **JN51xx Encryption Tool (JET) User Guide**

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**JN51xx Encryption Tool (JET)  
User Guide**

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## Preface

This manual describes the operation of the JN51xx Encryption Tool (JET) which can be used to produce encrypted and/or merged binary image files to be programmed into the Flash memory device (internal or external) of an NXP JN51xx wireless microcontroller. The tool is currently included in the JN516x and JN517x Software Developer's Kits (SDKs).

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## Organisation

This manual consists of 4 chapters and 3 appendices, as follows:

- [Chapter 1](#) introduces JET and its modes of operation
- [Chapter 2](#) describes how to prepare files for input into JET
- [Chapter 3](#) details the operational modes of JET
- [Chapter 4](#) describes how to load binary images produced by JET into a Flash memory device
- The [Appendices](#) provide a number of use cases of JET, how to create a NULL OTA image and installation instructions for the Atomic Programming AP-114 device

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## Conventions

Files, folders, functions and parameter types are represented in **bold** type.

Function parameters are represented in *italics* type.

Code fragments are represented in the `Courier New` typeface.



This is a **Tip**. It indicates useful or practical information.



This is a **Note**. It highlights important additional information.



*This is a **Caution**. It warns of situations that may result in equipment malfunction or damage.*

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## Acronyms and Abbreviations

API	Application Programming Interface
CA	Certificate Authority
CRC	Cyclic Redundancy Check
HA	Home Automation
JET	JN51xx Encryption Tool
OTA	Over-the-Air
PCB	Printed Circuit Board
SDK	Software Developer's Kit
SE	Smart Energy
SPI	Serial Peripheral Interface
SSB	Second-Stage Bootloader
ZLL	ZigBee Light Link

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## Related Documents

JN-UG-3098	BeyondStudio for NXP Installation and User Guide
JN-UG-3109	JN517x LPCXpresso Installation and User Guide
JN-UG-3099	JN51xx Production Flash Programmer User Guide
JN-UG-3007	JN51xx Flash Programmer User Guide
JN-UG-3103	ZigBee Cluster Library User Guide (for ZLL/HA/SE)
JN-UG-3115	ZigBee Cluster Library User Guide (for ZigBee 3.0)
JN-UG-3059	ZigBee Smart Energy User Guide

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## Support Resources

To access online support resources such as SDKs, Application Notes and User Guides, visit the Wireless Connectivity area of the NXP web site:

[www.nxp.com/products/wireless-connectivity](http://www.nxp.com/products/wireless-connectivity)

All NXP resources referred to in this manual can be found at the above address, unless otherwise stated.

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## Trademarks

All trademarks are the property of their respective owners.

## 1. An Introduction to JET

The JN51xx Encryption Tool (JET) is a command-line utility which provides a means of preparing binary files for programming into the Flash memory device (internal or external) of an NXP JN516x or JN517x wireless microcontroller.

The tool is provided as an executable file, **JET.exe**, in the JN516x or JN517x Software Developer's Kit (SDK) at the following location:

**<JN51xx\_SDK\_ROOT>/Tools/OTAUtils/**

where **<JN51xx\_SDK\_ROOT>** is the directory in which the SDK is installed.

The executable can be launched from the above 'OTAUtils' file path.



**Note:** JET is only needed to prepare a binary image that requires certain pre-processing (encryption or merger) before being loaded into Flash memory. Single unencrypted images can usually be programmed into Flash memory directly (without JET).

Unencrypted binary images produced by JET can be loaded into JN516x/7x Flash memory using any of the following JN51xx Flash Programmer tools:

- JN51xx Flash Programmer built into 'BeyondStudio for NXP' and described in the *BeyondStudio for NXP Installation and User Guide (JN-UG-3098)*
- JN51xx Flash Programmer built into LPCXpresso (for JN517x) and described in the *JN517x LPCXpresso Installation and User Guide (JN-UG-3109)*
- JN51xx Production Flash Programmer (JN-SW-4107) described in the *JN51xx Production Flash Programmer User Guide (JN-UG-3099)*
- JN51xx Flash Programmer (JN-SW-4007) described in the *JN51xx Flash Programmer User Guide (JN-UG-3007)*



**Note:** The Flash programmer within 'BeyondStudio for NXP' and LPCXpresso cannot be used to erase and re-program JN516x/7x external Flash memory. However, the standalone JN51xx Flash Programmer utilities (JN-SW-4107 and JN-SW-4007) can be used to program JN516x/7x internal and external Flash memory.

Alternatively, a third party device, such as the Atomic Programmer AP-114 device, can be used to program JN516x/7x external Flash memory. The above JN51xx Flash Programmers (JN-SW-4107 and JN-SW-4007) always program the external Flash memory from offset zero, whereas the Atomic Programmer tool can program the Flash memory from any offset.

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## 1.1 Purpose of JET

JET can be used to perform the following operations on a binary image:

- To encrypt a binary file before it is stored in JN516x/7x external Flash memory - this secures the application (and associated data), which is particularly recommended for ZigBee PRO Smart Energy
- To combine two or more binary files (unencrypted) into a single binary image - this facility is used for ZigBee Over-the-Air (OTA) Upgrade, which may involve the programming of a single image containing more than one software component
- To generate an OTA upgrade image (signed or unsigned, with or without CRC)

The above features of JET are described in more detail in [Section 1.2](#), which outlines the available operational modes of the tool.



**Note:** For more information on ZigBee OTA Upgrade, refer to the chapter on this cluster in the *ZigBee Cluster Library User Guide (JN-UG-3103 or JN-UG-3115)*.

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## 1.2 Modes of Operation

JET offers three modes of operation:

- Binary Encryption mode, described in [Section 1.2.1](#)
- Combine mode, described in [Section 1.2.2](#)
- OTA Merge mode, described in [Section 1.2.3](#)

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### 1.2.1 Binary Encryption Mode

In Binary Encryption mode, JET takes an application binary file as input and produces an encrypted binary file as output. The input file is a normal application binary file built for the JN516x/7x device.

In this mode, the user is required to provide:

- unencrypted binary application file
- name of the encrypted output file
- encryption key
- initialisation vector

The encryption key is stored in the index sector from where it is retrieved during decryption. The key comprises four 32-bit words, which are stored in Little Endian format.

The use of JET in Binary Encryption mode is detailed in [Section 3.1](#).

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## 1.2.2 Combine Mode

In Combine mode, JET takes an application binary file and a configuration file (containing serialisation data) as inputs, and produces a binary file as its output which incorporates the serialisation data. The input file is an unencrypted application image file built for the JN516x/7x device and the configuration file is as detailed in [Section 2.3](#).

The use of JET in Combine mode is detailed in [Section 3.2](#).

---

## 1.2.3 OTA Merge Mode

OTA Merge mode allows the creation of binary images for applications which support the ZigBee Over-the-Air (OTA) Upgrade cluster. This mode can be used to produce a new OTA server image by combining the following unencrypted images:

- initial server image
- client upgrade application

The combined image can then be loaded into the external Flash memory of the JN516x/7x device on the OTA server node. The initial server image will be loaded into the internal Flash memory of the JN516x/7x device.



**Note:** This mode is only likely to be used during development to test the OTA upgrade functionality.

A client upgrade image must have an OTA header attached at the beginning of the image. This image must also be put at the correct offset in Flash memory.

If one of the standalone JN51xx Flash Programmer utilities (JN-SW-4107 or JN-SW-4007) is used to load the binary images, the programming must always start from the beginning of Flash memory. In this case, a new client image which is to be loaded onto the server must first be combined with the server application so that Flash memory can be completely re-written. Other Flash programming tools, such as the Atomic Programming AP-114 device, may allow a new client image to be written directly to the appropriate offset in Flash memory on the server, without a merger and complete re-write.

An application image contains a 4-byte version number field at the start of the image, which is not needed. The standalone JN51xx Flash Programmer utilities automatically strip out this field but other Flash programming tools, such as the AP-114 device, do not. OTA Merge mode provides an option to remove this field when using such tools.

The use of JET in OTA Merge mode is detailed in [Section 3.3](#). Information on ZigBee OTA Upgrade can be found in the *ZigBee Cluster Library User Guide (JN-UG-3103 or JN-UG-3115)*.

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## 1.3 Use Cases of JET

This section contains flow diagrams that illustrate ‘use cases’ for JET. Often, it is necessary to use the tool in a succession of modes. The required JET commands for the illustrated cases are detailed in [Appendix A](#).

The scenarios that produce unencrypted outputs are likely to be use in a development environment, while those that produce encrypted outputs are likely to be used in a production environment.

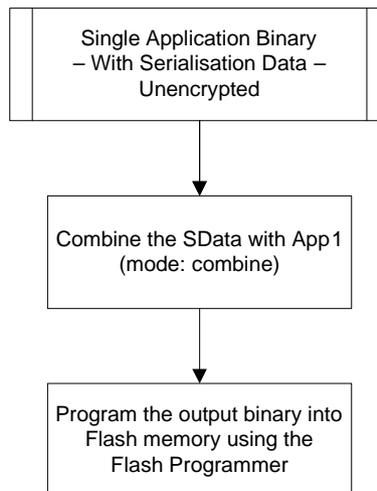
Note that the following abbreviations are used in the flow diagrams:

- EncKey – Encryption Key
- SData or SD – Serialisation Data
- App1 - Application image 1

---

### 1.3.1 Use Case 1: Single App with SD - Unencrypted

In this case, a single application binary is first combined with serialisation data using Combine mode. The final (unencrypted) output file is written to Flash memory.



**Figure 1: Single Application with SD - Unencrypted**

## 1.3.2 Use Case 2: Single App with Blank SD - Encrypted

In this case, a single application binary with no serialisation data is encrypted using Binary Encryption mode and merged with blank serialisation data using combine mode. The encrypted output file is written to Flash memory.

**1** **Note:** Since there is no serialisation data, the space reserved for this data in the application image is left blank (all Fs).

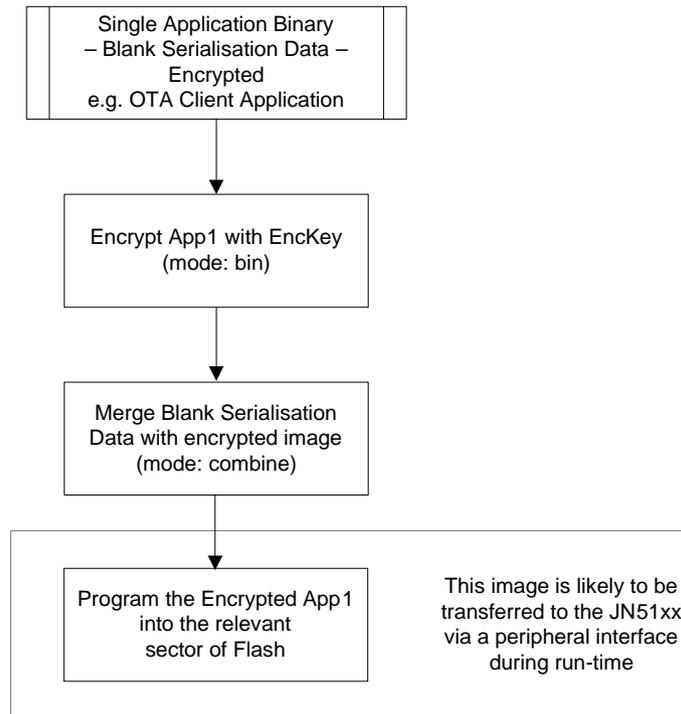


Figure 2: Single Application with Blank SD - Encrypted

## 1.4 Serialisation Data

An application may require information which allows it to identify and authenticate the host device on which the application is intended to be run - this is particularly the case for a ZigBee Smart Energy (SE) application which requires a high level of security. This information is called 'serialisation data' and it must reside in the Flash memory of the host device along with the application binary.



**Note:** The JET software provided in the JN516x ZigBee Smart Energy SDK (JN-SW-4164) supports the use of serialisation data for Smart Energy security. However, you will need to request certain data from a Certificate Authority (see below).

The serialisation data contains the following information:

Data Component	Size (bytes)	Domain
IEEE/MAC address (if not programmed into eFuse)	8	Device
Pre-configured link key (derived from an installation code)	16	SE-specific
Security certificate (from Certificate Authority such as Certicom)	48	SE-specific
Private key (associated with security certificate)	21	SE-specific
Security certificate (from Certificate Authority such as Certicom)	74	SE-specific
Private key (associated with security certificate)	36	SE-specific

**Table 1: Serialisation Data**

This information is unique for each JN516x/7x device and is provided as follows:

- **IEEE/MAC address:** This 64-bit address is provided by NXP.
- **Pre-configured link key:** This 128-bit key is derived (using an algorithm) from an installation code consisting of a random sequence of hexadecimal values. The installation code is printed on a label for the device during manufacture. The derived key is also stored in Flash memory for the device. The key must be derived again from the installation code in the same way in order to be included in the serialisation data.
- **Security certificate:** This is obtained from a Certificate Authority (CA) such as Certicom by submitting the IEEE/MAC address of the device. The certificate includes this address as well public keys for the device and the CA.
- **Private key:** This is obtained from the CA along with the security certificate.

Further details of the above security certificate and keys can be found in the *ZigBee Smart Energy User Guide (JN-UG-3059)*.

For JN516x/7x, only the private key must be encrypted, using the device's index sector key. JET provides an option in Combine mode for encrypting the private key.

Preparing the serialisation data for input to JET is described in [Section 2.3](#).

## 2. Preparing an Application for JET

In order to use JET to encrypt a binary application and/or merge binary files, you must prepare the application and its associated files for input into JET:

- Adapt the makefile for the application, as described in [Section 2.1](#)
- Adapt the application code itself, as described in [Section 2.2](#)
- Prepare a serialisation data file (if required), as described in [Section 2.3](#)

### 2.1 Adapting the Makefile

The makefile for your application needs to reserve locations in JN516x/7x Flash memory where the OTA header and security certificate/keys (if required) will be stored. To do this, add the following tags for each `$(OBJCOPY)` in the makefile:

```
-j .ro_mac_address -j .ro_ota_header -j .ro_se_lnkKey
-j .ro_se_cert -j .ro_se_pvKey -j .ro_se_283k1_cert
-j .ro_se_283k1_pvKey
```

where:

- `-j .ro_mac_address` refers to the device's MAC address.
- `-j .ro_ota_header` refers to the OTA header and is only required when using the ZigBee OTA Upgrade cluster.
- The remaining tags relate to the serialisation data required for encryption (see [Section 1.4](#)) and have the following meanings:
  - `-j .ro_se_lnkKey` refers to the pre-configured link key
  - `-j .ro_se_cert` refers to a security certificate
  - `-j .ro_se_pvKey` refers to the private key associated with the above certificate
  - `-j .ro_se_283k1_cert` refers to a security certificate
  - `-j .ro_se_283k1` refers to the private key associated with the above certificate

These five tags are primarily needed for Smart Energy applications - for more information on Smart Energy security, refer to the *ZigBee Smart Energy User Guide (JN-UG-3059)*.

If required, these tags should be added after `-j .vsr_handlers` and before `-j .rodata`.

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## 2.2 Adapting the Application Code

This section describes the adaptations to application code that are needed to use security-related serialisation data (on any device).

---

### 2.2.1 Serialisation Data

The makefile updates described in [Section 2.1](#) ensure that the security-related serialisation data place-holders will be included within the application image. These place-holders will be populated either during production programming or by JET when used in Combine mode. In order for the application to access these place-holders, the following must be defined within the code:

```
PUBLIC uint32 au32SeZcertificate[48] __attribute__ ((section
(".ro_se_cert")));
uint8* au8Certificate = (uint8*)au32SeZcertificate;

PUBLIC uint32 au32SePrvKey[21] __attribute__ ((section
(".ro_se_pvKey")));
uint8* au8PrivateKey = (uint8*)au32SePrvKey;

PUBLIC uint8 au8LnkKeyArray[16] __attribute__ ((section
(".ro_se_lnkKey")));

PUBLIC uint8 au8Sect23k1Certificate[74] __attribute__ ((section
(".ro_se_283k1_cert")));

PUBLIC uint8 au8Sect23k1PrivateKey[36] __attribute__ ((section
(".ro_se_283k1_pvKey")))
```

The elements of the above arrays must be set to 0xFF, to allow the production programming of serialisation data. Alternatively, to aid application development, the 0xFF values can be replaced with hardcoded serialisation data. For an example of this, refer to any of the **app\_certificates.h** files in the Application Note *ZigBee Smart Energy HAN Solutions (JN-AN-1135)*.

The following is also required for JN516x/7x devices:

```
PUBLIC uint8 au8DeviceMacAddress[8] __attribute__ ((section
(".ro_mac_address")))
```

The above MAC address container can be over-ridden in the application by calling the following function:

```
ZPS_vSetOverrideLocalMacAddress(au8DeviceMacAddress);
```

## 2.3 Setting Up Serialisation Data File

Serialisation data is required for a ZigBee PRO Smart Energy (SE) application which is to use SE security and for any application in which the IEEE/MAC address of the host device(s) must be encoded (for example, if this address is not available in eFuse on the device). For an introduction to serialisation data, refer to [Section 1.4](#).



**Note:** The JET software provided in the JN516x ZigBee Smart Energy SDK (JN-SW-4164) supports the use of serialisation data for Smart Energy security. However, you will need to request certain data from a Certificate Authority (see below).

The serialisation data for a device consists of up to four components (the last three components will be required only if security is to be implemented):

- IEEE/MAC address
- Security certificate
- Private key (associated with certificate)
- Pre-configured link key

This data is obtained and assembled as described below. Ultimately, JET must reference the data for all relevant devices through a single configuration file.

### **Step 1 Produce a file containing the IEEE/MAC address(es) for the host device(s)**

The 64-bit IEEE/MAC addresses for all the devices on which the application is to run should be listed in a text file called **mac.txt**. This file contains one IEEE/MAC address per line, as illustrated below:

```
00158d0000000001  
00158d0000000002  
00158d0000000003
```

If the security components of the serialisation data are required, continue to the next step, otherwise go to Step 4.

**Step 2 Obtain the security certificate(s) and associated private key(s) from Certicom**

Submit the **mac.txt** file to a Certificate Authority (CA), such as Certicom ([www.certicom.com](http://www.certicom.com)), to request a security certificate and associated private key for each device with a listed address.

Certicom will return two text files, each containing the relevant data values for the devices, listed in the same device order as in the **mac.txt** file:

- **cert.txt**, which lists the security certificates, one certificate per line - for example:

```
0207b2e0472c4bf90c0bacc25436547815fd7702cbfa0022080c9df367ed5445  
535453454341c327a4e617f82378ec98
```

```
02068c968f6dfc191ff646881918f364ba4ef5e52769304367e78348fc455445  
535453454341348f56c2374945bc9290
```

```
020363366ca613ffa9249990d7a454829fe0d9b2e874921bc71b32f56c235445  
53545345434174865191c2dc72e3dd37
```

```
030785a63508b65d6d66cd7e098f27da653d70b13f7773da29260a2ce93d5445  
53545345434123d649ca123f46e5732d
```

- **key.txt**, which lists the associated private keys, one key per line - for example:

```
02b08cd381b00593a6b3e1ab04a5a7ddd0a9f0834
```

```
02b9475dc6346089d5d3c278ac83544b7a5bfa97de
```

```
009c399b93536f1855a65b7b786f56fe75be52943e
```

```
012d7c171cb5973e38586cf31efc9eace2f0d58d7a
```

**Step 3 Produce a file containing the pre-configured link key(s) for the host device(s)**

For each host device, generate the 128-bit pre-configured link key from the installation code for the device. The installation code consists of 12, 16, 24 or 32 random hex digits (followed by a 4-digit checksum of the random digits) and is printed on a label distributed with the device. The link key is pre-programmed into Flash memory for the device during manufacture and you must use the same algorithm as used by the manufacturer to derive the link key from the installation code.

List the link keys for the host devices in a text file called **link.txt**, with one key per line and listed in the same device order as in the **mac.txt** file, as illustrated below:

```
00112233445566778899aabbccddeeff
```

```
10112233445566778899aabbccddeeff
```

```
20112233445566778899aabbccddeeff
```

**Step 4 Produce a configuration file which references the serialisation data file(s)**

Create a text file which collects together all the serialisation data for the application by referencing the above files. This 'configuration file' will act as an input to JET.

The configuration file must list the serialisation data files and for each, give the address of the start location in Flash memory where its data will be stored and the length of the data (in bytes). The file can be named as desired (e.g. **config.txt**).

The exact contents of the configuration file depend on the target device type, examples are provided below:

**For JN516x/7x without OTA Upgrade Cluster:**

```
MACaddr.txt,0044,8  
LinkKey.txt,0054,16  
ZigbeeCert.txt,0064,48  
PrivateKey.txt,0094,21  
ZigbeeCert2.txt 0104,74  
PrivateKey2.txt 0154,36
```

**For JN516x/7x with OTA Upgrade Cluster:**

```
MACaddr.txt,0044,8  
LinkKey.txt,00a4,16  
ZigbeeCert.txt,00b4,48  
PrivateKey.txt,00e4,21  
ZigbeeCert2.txt 0104,74  
PrivateKey2.txt 0154,36
```



**Note:** If security is not to be implemented, the configuration file need only contain details of the IEEE/MAC address file.

**Chapter 2**  
***Preparing an Application for JET***

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## 3. Creating an Application Image

This chapter describes how to use JET in the modes introduced in [Section 1.2](#):

- Binary Encryption mode - see [Section 3.1](#)
- Combine mode - see [Section 3.2](#)
- OTA Merge mode - see [Section 3.3](#)

Further options that are required for OTA Upgrade are presented in [Section 3.4](#).

To use the tool, first launch a command-line window on your PC.



**Note 1:** JET can be run from any directory. The example commands in this chapter assume that all input files and the **JET.exe** file are located in the same directory.

**Note 2:** For command-line help when using the tool, enter `JET.exe -h` at the command prompt.

**Note 3:** In the case of the JN516x/7x device, encryption of the device's own application binary is not necessary. Encryption is only required for OTA upgrade images, as they will be stored in external Flash memory.

## 3.1 Using Binary Encryption Mode

In Binary Encryption mode (`bin`), JET takes an application binary file as input and produces an encrypted binary file as output (see [Section 1.2.1](#)).

The tool is run in this mode by entering the following on the command line:

```
JET.exe -m bin -v <device type> -f <input filename>.bin  
-e <output filename>.bin -k <encryption key> -i <ivector>
```

where:

- `-m bin` is the desired mode of JET: Binary Encryption mode
- `-v <device type>` is the device type, as one of the following strings:
  - JN516x
  - JN517x
- `-f <input filename>.bin` is the name of input binary file which is to be encrypted
- `-e <output filename>.bin` is the name of the encrypted output file to be produced
- `-k <encryption key>` is the encryption key to be used. This key comprises four 32-bit words and must be specified as a hexadecimal number in Little Endian format (for an example, see below). You can prefix this number with '0x' to indicate a hex value, if you wish
- `-i <ivector>` is the initialisation vector for encryption which must be specified for the JN516x/7x devices (note that the 8 least significant hexadecimal digits of this value must be zero)

If the encrypted binary file is to be used as an OTA Upgrade image (for example, an upgrade image for an OTA Upgrade cluster client) then further options must be added to the `JET.exe` command. These options are described in [Section 3.4](#).

### Example Command

The following example illustrates the above command for Binary Encryption mode:

```
JET.exe -m bin -v JN516x -f input.bin -e output.bin  
-k 12345678abcdef12aaaaaaaaabbbbbbbb  
-i 00000010111213141516171800000000
```



**Note:** Since the encryption key must be specified in Little Endian format, '12345678' represents the least significant word of the 4-word key in the example.

## 3.2 Using Combine Mode

In Combine mode (`combine`), JET allows an unencrypted application binary file and a configuration file containing serialisation data to be combined into a single unencrypted binary file. An option exists in this mode which allows the output file to be encrypted in the future.

The tool is run in this mode by entering the following on the command line:

```
JET.exe -m combine -v <device type> -f <application filename>.bin
-x <config filename>.txt -a <padding> -g <private key encrypting
option> -k <encryption key>
```

where:

- `-m combine` is the desired mode of JET: Combine mode
- `-v <device type>` is the device type, as one of the following strings:
  - JN516x
  - JN517x
- `-f <application filename>.bin` is the name of input application binary file, which is unencrypted
- `-x <config filename>.txt` is the name of the input configuration file which contains the serialisation data
- `-a <padding>` indicates whether the data is to be padded to align it to a 16-byte boundary, so that it can be encrypted in the future: '1' padded, '0' not padded
- `-g <Private Key Encrypt Option>` specifies whether or not to encrypt the private key: '1' encrypted, '0' not encrypted
- `-k <Encryption Key>` key used for encrypting private key

The tool produces an output binary file **output<MAC address>.bin**, where the filename contains the MAC address of the target device for the image.

### Example Command

The following example illustrates the above command for Combine mode:

```
JET.exe -m combine -f IPD_NODE_JN5168.bin -x config.txt -v JN516x
-g 1 -k 0x11111111222222223333333344444444
```

---

## 3.3 Using OTA Merge Mode

OTA Merge mode (`otamerge`) allows the creation of a binary image for the ZigBee OTA Upgrade cluster by merging two separate components into a single file (see [Section 1.2.3](#)). The input files can be provided both encrypted or both unencrypted, in which case the output file will be encrypted or unencrypted, respectively.

The tool is run in this mode by entering the following on the command line:

```
JET.exe -m otamerge -v <device type> -s <input filename1>.bin  
-c <input filename2>.bin -o <output filename>.bin -i <ivector>  
--sector_size=SECTOR_SIZE --sign_integrity <sign or integrity>  
-x <config filename>.txt -p <Flash prog> --ota --embed_hdr  
--donotembedcrc
```

where:

- `-m otamerge` is the desired operational mode of JET: OTA Merge mode
- `-v <device type>` is the device type, as one of the following strings:
  - JN516x
  - JN517x
- `-s <input filename1>.bin` is the name of the first input binary file or the initial OTA cluster server image
- `-c <input filename2>.bin` is the name of the second input binary file, normally the cluster server application or client application
- `-o <output filename>.bin` can be optionally used to specify the name of the output file to be produced (if this is not specified, the options `-u`, `-t`, `-n` below will be used to generate the output filename)
- `-i <ivector>` is the initialisation vector for encryption which must be specified for the JN516x (note that the 8 least significant hexadecimal digits of this value must be zero)
- `--sector_size=SECTOR_SIZE` is the sector size (in bytes) to which the client image must be aligned
- `--sign_integrity <sign or integrity>` updates the image size to accommodate the signature and signature certificate fields or the integrity field (for image signing, must be used with the `-x` option):
  - 0 - No sign or integrity code (default)
  - 1 - Image Signature for Curve 1
  - 2 - Image Signature for Curve 2
  - 3 - Image Integrity code
- `-x <config filename>.txt` is the name of the input configuration file which contains the signing data for use with the `--sign_integrity` option

- `-p <Flash prog>` indicates whether JET is to strip out the 4-byte version number field at the start of an image for a JN516x/7x device - this setting depends on the tool to be used to load the output image into Flash memory:
  - '0' instructs JET to leave the field in the file and is for use with a standalone JN51xx Flash Programmer utility which strips out the field itself (default)
  - '1' instructs JET to strip out the field and is for use with programming tools that do not themselves remove the field (e.g. AP-114)
- `--ota` incorporates the OTA header at the beginning of the application binary as well as the tag headers (tag id, e.g. 0x0000 and tag length). This option should be used for generating an OTA upgrade binary
- `--embed_hdr` embeds the OTA header in the output file
- `--donotembedcrc` omits the CRC value from the output image (by default, the CRC value is included in both encrypted and unencrypted images) - this option can only be used in conjunction with `--embed_hdr` (above)

The options for generating the output filename are described below.

For all the application binaries which support the OTA Upgrade cluster, the OTA header must be embedded in the actual image.

## Output Filename

The output filename can be optionally specified as part of the above JET command using the `-o` option. If this option is not specified, the OTA options `-u`, `-t`, `-n` (described in [Section 3.4](#)) will be used to generate an output filename of the format:

**UUUU-TTTT-NNNNNNNN-upgradeMe.zigbee**

where:

- UUUU is the manufacturer ID specified using the `-u` option
- TTTT is the image type specified using the `-t` option
- NNNNNNNN is the file version specified using the `-n` option and has the format indicated in [Section 3.4](#)
- Each of the above values is expressed in hexadecimal and in upper case
- The file extension of the generated output filename is **.zigbee**
- If any of the above three options is not specified, the default value for that option will be used

For example, if the following command is entered

```
JET.exe -m otamerge -v JN516x -s app1.bin -c app2.bin -u 0x4A4E  
-t 0x5168 -n 0x15050126 --ota --embed_hdr
```

then the generated output filename will be:

**4A4E-5168-15050126-upgradeMe.zigbee**

## Image Signing

The `--sign_integrity` option used alone will modify the output file size to include space for the signing fields, but these fields will not contain any signing data. To populate these fields, the `-x` option must be used to provide an input configuration file containing the following data in the following order:

- Private key (associated with certificate)
- IEEE/MAC address of signer (provided in Little Endian format)
- Security certificate of signer

This configuration file is created as described in [Section 2.3](#).

JET will produce two output files - one containing an unsigned image (contains space for signing fields but no data) and one containing a signed image, where the filename of the latter is prefixed with **Signed\_**.

For example, the command

```
JET -m otamerge --sign_integrity 1 -x sign_config.txt --ota  
--embed_hdr -c IPD_NODE_JN5168.bin -u 0x4A4E -t 0x5168 -n 0x15050126  
-o output.bin
```

will result in the output files **output.bin** (unsigned) and **Signed\_output.bin** (signed).

## CRC Value

A Cyclic Redundancy Check (CRC) value is included in all encrypted and unencrypted images, by default. In OTA Merge mode, the CRC value can be left out of the output image by incorporating the `--donotembedcrc` option. This option can only be used in conjunction with the `--embed_hdr` option (embed OTA header).

An example command to create an output image with no CRC value is:

```
JET.exe -m otamerge -v JN516x -s input_file1.bin -c input_file2.bin  
-o output_file_with_no_CRC.bin --ota --embed_hdr --donotembedcrc
```

## Example Commands

The examples below show a sequence of commands to create encrypted binary images for a (Smart Energy) IPD and Metering Device, which are acting as the OTA Upgrade cluster client and server respectively, and run on a JN5168 device. The output binaries should be loaded into JN5168 Flash memory using one of the standalone JN51xx Flash Programmer utilities (which automatically strip out the 4-byte version number field at the start of the image).

```
::: Server Preparation :::  
REM add serial data to the METER binary  
JET.exe -m combine -f METER_NODE_JN5168.bin -x configOTA_ESP.txt  
-v JN516x -g 1 -k 0x11111111222222223333333344444444  
  
REM Create a Server binary file which will be used to program  
internal Flash  
JET.exe -m otamerge --embed_hdr -c output0000000000000002.bin  
-o Server.bin -v JN516x -n 1
```

```
pause
:::::: Server Preparation - END ::::::

:::::: CLIENT SIDE ::::::
REM add serial data to the IPD binary
JET.exe -m combine -f IPD_NODE_JN5168.bin -x configOTA_IPD.txt
-v JN516x -g 1 -k 0x1111111122222222333333333444444444

REM Create a client file which will be used to program internal Flash
JET.exe -m otamerge --embed_hdr -c output0000000000000001.bin -o
Client.bin -v JN516x -n 1
:::::: CLIENT SIDE End ::::::

:::::: Upgrade Image Preparation ::::::
REM Prepare an upgrade image with higher version number embedded in
it
JET.exe -m otamerge --embed_hdr -c IPD_NODE_JN5168.bin
-o UpGradeImagewithOTAHeader.bin -v JN516x -n 2

REM Encrypt the data for the upgrade image
JET.exe -m bin -f UpGradeImagewithOTAHeader.bin
-e Enc_UpGradeImagewithOTAHeader.bin
-k 0x1111111122222222333333333444444444
-i 0000000010000000000000000000000000000000 -v JN516x

REM Put 0xFF at the location of serialisation data after encryption,
so that the original data can be copied from the existing image
JET.exe -m combine -f Enc_UpGradeImagewithOTAHeader.bin
-x configOTA6x_BLANK_IPD.txt -v JN516x

REM Create the upgrade image to merge with the encrypted server, let
the image have the version number
JET.exe -m otamerge --ota -c outputfffffffffffffffffff.bin
-o OTA_ENC_UpGradeImagewithOTAHeader.bin -v JN516x -n 2
:::::: Upgrade Image Preparation -END ::::::
```

---

## 3.4 OTA Options

If a file to be encrypted using Binary Encryption mode ([Section 3.1](#)) is to be used as an OTA Upgrade image (for example, an upgrade image for an OTA Upgrade cluster client) then further options must be added to the `JET.exe` command. These options relate to the contents of the OTA header and are as follows:

- `-u MANUFACTURER, --manufacturer=MANUFACTURER` is the manufacturer code (default: 0x4A4E)
- `-t IMAGE_TYPE, --image_type=IMAGE_TYPE` is the OTA header image type (user-defined)
- `-r HEADER_VERSION, --Header_Version=HEADER_VERSION` is the OTA header version (default: 0x0100)
- `-n FILE_VERSION, --File_Version=FILE_VERSION` is the OTA file version - for format, see below (default: 0x1)
- `-z STACK_VERSION, --Stack_Version=STACK_VERSION` is the OTA stack version (default: 0x002)
- `-d MAC, --destination=MAC` is the IEEE/MAC address of the destination node
- `--security=VERSION` is the security credential version
- `--hardware=MIN MAX` is the hardware minimum and maximum versions
- `--ota` puts the OTA header at the start of the image in any of the encryption modes. The OTA header is embedded inside the image before encrypting the image (default: false)

### File Version Format

The OTA file version, specified using the `-n` option, has the format illustrated in the following examples:

- 0x10053519 represents application release 1.0, build 05, with stack release 3.5 b19
- 0x10103519 represents application release 1.0, build 10, with stack release 3.5 b19
- 0x10103701 represents application release 1.0, build 10, with stack release 3.7 b01

## 4. Loading an Application Image

This chapter describes how to load a binary image, prepared using JET, into the Flash memory associated with of a JN516x/7x device.

### 4.1 Flash Programming Tools/Devices

The Flash memory connected to a JN516x/7x device is normally programmed using one of the following JN51xx Flash Programmer software tools:

- JN51xx Flash Programmer built into 'BeyondStudio for NXP' and described in the *BeyondStudio for NXP Installation and User Guide (JN-UG-3098)*
- JN51xx Flash Programmer built into LPCXpresso (for JN517x) and described in the *JN517x LPCXpresso Installation and User Guide (JN-UG-3109)*
- JN51xx Production Flash Programmer (JN-SW-4107) described in the *JN51xx Production Flash Programmer User Guide (JN-UG-3099)*
- JN51xx Flash Programmer (JN-SW-4007) described in the *JN51xx Flash Programmer User Guide (JN-UG-3007)*



**Note:** The Flash programmer within 'BeyondStudio for NXP' and LPCXpresso cannot be used to erase and re-program JN516x/7x external Flash memory.

The above standalone JN51xx Flash Programmers (JN-SW-4107 and JN-SW-4007) always program the JN516x/7x external Flash memory from offset zero. In order to overcome this limitation, NXP recommend the programming of external Flash devices using a third-party Flash programmer which can program the Flash memory from any offset - for example, the Atomic Programming AP-114 device which can be ordered from [www.atomicprogramming.com](http://www.atomicprogramming.com). This allows the Flash device to be programmed directly via the SPI interface of the JN516x/7x device.



**Note:** PCB design should accommodate access to the SPI bus. SPI programming has the added advantage of higher baud-rates. Another advantage of using a third-party SPI Flash programmer is that the Flash devices can be programmed prior to PCB assembly.

The remainder of this chapter describes loading a binary file into JN516x/7x external Flash memory using the Atomic Programming AP-114 device. Use of this device involves connecting the device to both a source PC and the target Flash memory device. Software for the AP-114 must be installed on the PC - the Programming Centre (ApPC) software and the necessary device drivers. Installation instructions for this software are provided in [Appendix B](#).

---

## 4.2 Programming the Flash Device

This section describes how to use the Atomic Programming AP-114 device (see [Section 4.1](#)) to load a binary file into the external Flash memory associated with a JN516x/7x device. The Flash programming instructions assume the following prerequisites:

- The Atomic Programming ApPC software and device drivers have been installed on the PC - installation instructions are provided in [Appendix C.1](#) and [Appendix C.2](#).
- The AP-114 device has been connected to the PC and to the target device - the required connections to the carrier board of a JN516x/7x device are detailed in [Appendix C.3](#).



**Note:** Make sure that the Programming Center (ApPC) software is version 1.3 or above. The latest version is available directly from the Atomic Programming web site ([www.atomicprogramming.com](http://www.atomicprogramming.com)).

The Flash programming instructions are provided in the sub-sections below.

---

### 4.2.1 Setting Up the Serialisation Data

If programming an encrypted binary file, before starting the ApPC software on the PC, you must point this software at the encrypted licence file containing the serialisation data - this is a **.txt** file produced by JET in Data Serialisation mode (see [Section 3.2](#)).

To do this, edit the script file **Ap\_Jennic\_Encrypted\_File.ser** in the directory **C:\Program Files\Atomic Programming\ApPC\Scripts** by changing line 21 from

```
Const FILENAME = "c:\Programmer\output.txt"
```

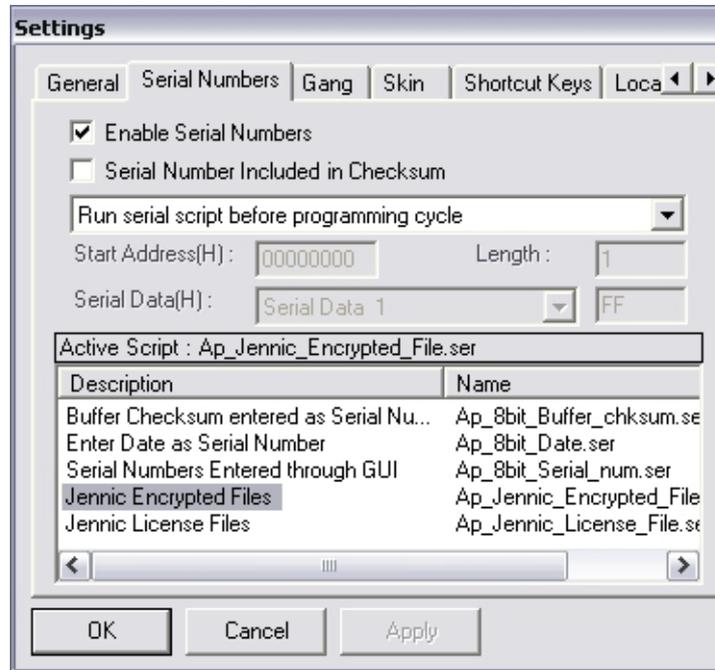
to point to the relevant file.

---

### 4.2.2 Writing to the Flash Device

1. Ensure that the AP-114 device is connected to the PC and to the carrier board of the JN516x/7x device (for details of the latter connection, see [Appendix C.3](#)).
2. Start the ApPC software on the PC (there should be a 'Programming Center' icon on your desktop).  
The ApPC main window will appear.
3. Select the correct Flash device (this will probably be a Numonix M25P10A or M25P40) and select the package as ISP (this is because the target platform is self-powered).

4. Enable the serial numbers as follows (and as indicated in the screenshot below):
  - a) Click **Settings** and then, in the **Settings** window, select the **Serial Numbers** tab.
  - b) Ensure that the **Enable Serial Numbers** checkbox is ticked, select the option **Run serial script before programming cycle** from the drop-down menu and then select **Jennic Encrypted Files** from the list.
  - c) Click **OK**.



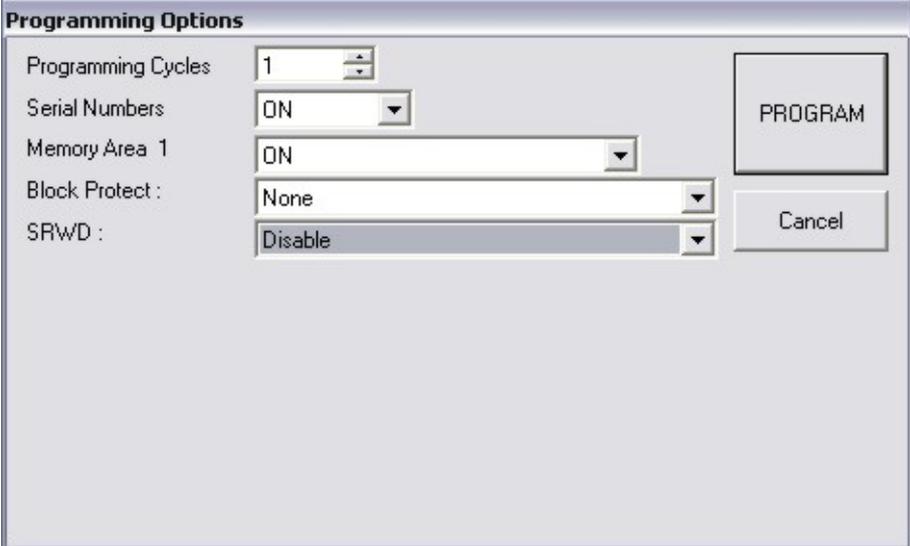
5. Click **File** in the main window and then click **Open**. Use the **Browse** button to select the binary file to be loaded, leaving the other options as shown in the screenshot below.



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**Loading an Application Image**

6. Click **Open** to load this data into the programmer tool.  
Note that the data buffer can be viewed/edited using the **Buffer** window, if required.
7. Follow the path **Action > Program** to display the following **Programming Options** window.

 **Note:** In this application, the protection features in the Flash device are not required and have been set to 'Block Protect : None' and 'SRWD : Disable'.



**Programming Options**

Programming Cycles: 1

Serial Numbers: ON

Memory Area 1: ON

Block Protect : None

SRWD : Disable

PROGRAM

Cancel

8. Click **Program** to load the binary file into the target Flash device.

 **Note:** When exiting the software, the above settings will be saved.

## Appendices

### A. Use Cases

This appendix details the commands for nine use cases of JET. Use cases 1 and 2 are introduced and illustrated in [Section 1.3](#).

Note that the following abbreviations are used:

- EncKey – Encryption Key
- SData or SD – Serialisation Data
- App1 – Application image 1
- App2 – Application image 2

#### A.1 Use Case 1: Single App with SD - Unencrypted

Combine SD with App1 to produce **output<MAC addr>.bin**:

```
JET.exe -m combine -v JN516x -f App1.bin -x App1_config.txt
```

#### A.2 Use Case 2: Single App with Blank SD - Encrypted

Encrypt the application binary:

```
JET.exe -m bin -v JN516x -f App2.bin -e EncApp2.bin  
-k 11223344556677880102030405060708  
-i 01020304050607080102030405060708
```

#### A.3 Use Cases 3-6: Adding OTA Header to an App Binary

This section provides different use cases of adding an OTA header to a ZigBee PRO application binary file.

##### Use Case 3: Adding OTA header and specifying output binary filename

```
JET.exe -m otamerge -v JN516x --ota --embed_hdr -u 0x4A4E -t 0x5148  
-n 0x10053519 -c EncApp1.bin -o BinwithOTAHeader.bin
```

##### Use Case 4: Adding OTA header and not specifying output binary filename

```
JET.exe -m otamerge -v JN516x --ota --embed_hdr -u 0x4A4E -t 0x5148  
-n 0x10053520 -c EncApp1.bin
```

##### Use Case 5: Adding OTA header and updating file size only (without signature data)

```
JET.exe -m otamerge -v JN516x --ota --embed_hdr --sign_integrity 1  
-u 0x4A4E -t 0x5148 -n 0x10053521 -c EncApp1.bin  
-o OTASignImageSizeUpdated.bin
```

## **Appendices**

### **Use Case 6: Adding OTA header and signature data**

```
JET.exe -m otamerge -v JN516x --ota --embed_hdr -u 0x4A4E -t 0x5148  
-n 0x10053522 --sign_integrity 1 -x sign_config.txt -c EncApp1.bin
```

## B. Creating a NULL OTA Image

This section details how to create a NULL upgrade image for ZigBee Over-The-Air (OTA) certification. A NULL upgrade image is a valid OTA file that has an image body without any real upgrade data inside. NULL images are small in size and are therefore useful for test purposes, since small files do not take much time to download. During testing, target devices may be required to:

- download NULL files without acting on the downloaded file
- ignore the image data in a NULL file but act on the OTA header accordingly

After the successful download of a NULL file, the target device must send an Upgrade End Request command back to the source device. The status value of the command may be either SUCCESS or INVALID\_IMAGE.

Below are examples of unsigned and signed NULL images which contain OTA headers but no valid image data.

### Sample NULL OTA Image (unsigned):

```
1E F1 EE 0B 00 01 38 00 00 00 4E 4A 48 51 03 00 00 00 02 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 3E 00 00 00 00 00 00 00 00 00
```

### Sample NULL OTA Image (signed):

```
1E F1 EE 0B 00 01 38 00 00 00 4E 4A 48 51 03 00 00 00 02 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 AC 00 00 00 00 00 00 00 00 00
```

The values in bold type in the examples above are described below (note that the fields are in Little Endian format):

- Manufacturer code - 4A4E
- Image type - 5148
- File version - 00000003

The above examples of unsigned and signed NULL images are used in the sub-sections below, which describe how to create a NULL image.

### B.1 Creating an Unsigned NULL Image

To create an unsigned NULL image, follow the steps below:

1. Create a text file, called **NullImage.bin**, using the first example above.
2. Modify the manufacture code, image type and file version, as required.
3. **NullImage.bin** is then the required NULL image upgrade file.

---

## B.2 Creating a Signed NULL Image

To create a signed NULL image, follow the steps below:

1. Create a text file, called **NullImage.bin**, using the second example above.
2. Modify the manufacture code, image type and file version, as required. Save the **NullImage.bin** file in the directory where JET is installed.
3. Run JET using the following command options (this example is for JN516x):

```
JET.exe -m otamerge -v JN516x --sign_integrity 1  
-x configSigner.txt -c NullImage.bin -o UpgradeImage.bin
```

This merges the supplied **NullImage.bin** file with the **configSigner.txt** file, which is present in the JET installation directory, and creates an output file **UpgradeImage.bin** for a JN516x device in this case.

4. **Signed\_UpgradeImage.bin** is then the required signed NULL image upgrade file.

---

## C. AP-114 Installation

The Atomic Programming AP-114 device is an example third-party Flash programmer that can be used here to load encrypted applications and serialisation data into the Flash memory of devices in a production environment.

The installation of the AP-114 programmer is in three parts:

- First the Atomic Programming PC software (ApPC) must be installed, as described in [Appendix C.1](#)
- Then the necessary device drivers for the AP-114 must be installed, as described in [Appendix C.2](#)
- When required, the AP-114 can be connected to the device to be programmed as described in [Appendix C.3](#)



**Note:** If you encounter any installation problems, before contacting Atomic Programming or your local sales office, please consult the manual and troubleshooting guide on the AP-114 installation CD.

For latest software updates, check:  
[www.atomicprogramming.com](http://www.atomicprogramming.com)

For support, help and advice, visit:  
[www.deviceprogrammers.net/forum](http://www.deviceprogrammers.net/forum)

---

### C.1 Installing the ApPC Software

To install the 'Programming Center' (ApPC) software for the AP-114 device:

1. Insert the Atomic Programming CD into the CD-ROM drive of your PC.  
Your web browser should start automatically. If the 'Welcome' HTML file does not load, double-click on **welcome.htm** in the directory window for your CD-ROM drive.
2. Browse to the Software page, select the ApPC link and select the RUN option.
3. Uncheck any components that you do not want to install (although it is recommended that all components are installed).
4. Read the License Agreement carefully and select **I Agree** to continue the installation.

The Microsoft .NET framework is automatically installed, if required, in addition to the selected components.

5. At the end of the installation, close the **Setup** dialogue box. There is no need to reboot your PC, but ensure that the CD is NOT removed (as it is needed for the next stage of installation, described in [Appendix C.2](#)).

---

## C.2 Installing the Device Drivers

To install the device drivers for the AP-114 device:

1. Connect the supplied USB cable to the back of the AP-114 device.
2. Connect the other end of the USB cable to a USB port on your PC. Windows should detect the programmer and launch the **Windows Found New Hardware Wizard**.

The Hardware Wizard helps to install the USB Control Port drivers for the programmer.

3. When asked if Windows can connect to Windows Update to search for software, select **No, not this time**.
4. Now select **Install from a list of specified locations**.
5. Browse to the **Driver** folder on the CD and click **Next**.



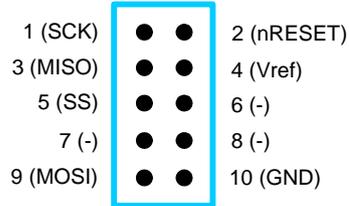
**Note:** Currently, the software has not passed Windows Logo testing, but it is completely safe to continue with the installation.

After the USB Control Port drivers have been installed, the wizard will launch again, this time to install the Device Programmer drivers.

6. Follow Steps 2-5 again to install the Device Programmer drivers, installing from the **Driver** folder on the CD.
7. Once the driver installation has completed, click **Finish**. There is no need to restart the PC.

### C.3 AP-114 to JN516x/7x Connection

To connect the AP-114 programmer directly to your hardware platform, use the 10-way Port 2 connector on the AP-114 device, shown below.



**Figure 3: AP-114 Port 2 SPI Mode Connector**

If you are using the AP-114 device with a board from an NXP JN516x/7x evaluation or development kit, such as the JN516x-EK004 Evaluation Kit, then a cable is required with the mapping shown in [Table 2](#) below.

Signal	AP-114 Port 10-Way Header	NXP 40-Way Expansion Header
SCK	1	22
MISO	3	23
MOSI	9	24
SS	5	25
nRESET	2	27
Vcc (Vref)	4	39
GND	10	40

**Table 2: Cable Mapping for NXP Board**

## ***Appendices***

## Revision History

Version	Date	Comments
1.0	19-Apr-2011	First release
1.1	23-May-2012	Combine mode and use cases added, as well as other updates and corrections
1.2	3-Sept-2012	OTA merge -p option added to specify Flash programming tool
1.3	15-Jan-2013	Updated for the JN516x chip family
1.4	18-Apr-2013	Improved appendix on creating a NULL OTA upgrade image
1.5	24-Feb-2015	Removed JN514x devices, renamed utility 'JN51xx Encryption Tool' and made other minor updates
1.6	14-Dec-2016	Updated for the JN517x chip family and for Smart Energy v1.2.1
1.7	24-Feb-2017	Added option to omit CRC value from OTA upgrade image and changed the way device type is specified from number to string

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