

## Technical Notes on using Analog Devices' DSP components and development tools

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## Boot Paging II: Maximizing Boot-Memory Efficiency on the ADSP-21xx family DSP's (excluding the ADSP-218x)

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### Introduction

This document provides various strategies to increase the efficiency and usefulness of standard boot memory in 21xx systems (excluding the ADSP-218x). The following topics are covered:

- Maximizing the efficiency of boot-page allocation within the boot memory of your ADSP-21xx system.
- Selecting the smallest boot memory device possible for your ADSP-21xx system.
- Creating multi-bank boot-page systems with 16 and 32 boot-pages.
- Mapping program memory and data memory into boot memory for large amounts of 8-bit wide storage.
- Modifying the boot memory image file.
- Description of an example system using all of the above concepts.

These methods can be complicated to implement, yet can effectively streamline certain applications.

For more information on boot-pages, see section 10.4 of the *ADSP-21xx Family User's Manual*, or the following Analog Devices Engineers Note: *Boot Paging I: FAQ - Boot Pages on the 21xx Family DSP's (excluding 218x & CSP01), #XXX*.

### Boot Memory Overview

The Analog Devices ADSP-21xx family of Digital Signal Processors (DSP) have a built-in booting

routine that loads 24-bit program memory (PM) into internal RAM from an 8-bit boot memory device. Booting can occur automatically when the DSP is reset and/or while the DSP is running. Boot memory is divided into eight pages. Each page holds an entire memory image of the DSP's internal PM. When configured to load PM from boot memory at reset, the DSP automatically loads boot-page 0.

Each 24-bit program memory word is stored in 4 bytes of boot memory. Therefore, the length of a boot-page (in bytes) is always 4 times the number of PM words stored within it.

This boot memory device is most commonly a ROM of some sort but can be any memory device (FLASH RAM, static RAM, or another processor) as long as it is fast enough and compatible with the DSP's external memory interface.

### Basic Boot Memory Interface

The standard method used to connect an ADSP-21xx DSP to boot memory is to connect pins A0-A13 of the external DSP bus to pins A0-A13 of the boot memory and pins D22 and D23 of the DSP to pins A14 and A15 of the boot memory. Pins A0-A12 cycle through the 8192 locations of each page. Pins A13, D22 and D23 select the page. This interface requires a minimum of 512 Kbits of boot memory.

The ADSP-21xx family DSPs built-in boot-page loading hardware assumes that the boot pages will be 8 Kbytes apart in boot memory. For example, boot page 0 starts at boot memory address 0, boot page 1 starts at boot memory address 0x2000(hex), etc. If your system uses a DSP that has less than 2Kwords of program memory, there is unused memory within each boot page in the boot memory. For instance, the ADSP-2115 has only 512 words of PM and requires 2 Kbytes of boot memory space per boot page. This leaves 6 Kbytes of boot memory unused per boot page. If the ADSP 2115 system uses all eight boot pages with this addressing scheme, the system requires 512 Kbits of boot

memory. This 512 Kbit boot memory has a maximum of  $2K \times 8 = 16$  Kbytes worth of boot data and a minimum of  $6K \times 8 = 48$  Kbytes of unused data. Figure 2 shows a memory map of this allocation scheme.

### Removing Unused Memory

By rewiring the address lines from the DSP to the boot memory, the unused memory (a minimum of  $6K \times 8 = 48$  Kbytes) is removed.

A DSP with 512 bytes of PM such as the ADSP-2105, 2115, 2163 and 2164, need only 2048 bytes to be read from each boot page because the internal PM is only 512 words long. By removing pins A11 and A12 from the boot memory and reconnecting pins A13, D22, and D23 (boot-page select lines) on the DSP to A11, A12 and A13 respectively, on the boot memory, the 6Kbytes per boot page that was previously unused is now eliminated and the pages are packed next to each other. The result is 8 boot pages stored in 128 Kbits of boot memory as opposed to the original 512 Kbits.

In a system that uses a DSP with 1K of PM such as the ADSP-2101, 2103, 2161, 2162 and 2111, each boot page is 4096 bytes in length because the internal PM is 1024 words long. Only pin A12 is removed and pins A13, D22 and D23 move down one address line. The result is 8 boot pages stored in 256 Kbits of boot memory verses the original 512 Kbits. Table 1 summarizes these relationships. For more information, see Section 5.4 in the *ADSP-2100 Assembler Tools and Simulator Manual*.

| Total PM in DSP (words) | Min. Size of BM (Kbits) | Address Lines Left Disconnected |
|-------------------------|-------------------------|---------------------------------|
| 512                     | 128                     | A11, A12                        |
| 1024                    | 256                     | A11                             |
| 2048                    | 512                     | (none)                          |

**Table 1 : DSP Boot Memory Sizes**

### Creating Multiple Boot-Page ‘Banks’

To create a system that uses more than 8 boot pages, the boot memory must be an order of 2x larger than the minimum size of boot memory as defined in Table 1. A boot memory size of 2x yields 16 boot pages: 4x yields 32 boot pages. Every time the boot memory is increased 2x, there is one

unused address line added as the most-significant unused address line of the boot memory. These unused lines can be tied to a memory mapped flip-flop in a DSP system.

To load a boot page from another bank first write to the flip-flop and specify the bank, then write to the System Control Register (SYSCON) and write the boot-page number. The unused bits may also be connected to hard switches, or to an entirely separate system. To connect these unused bits, the actual boot memory image file(s) created by the 21xx splitter must be modified. See “Modifying the Boot Memory Image file” section later in this article.

### Mapping PM or DM Space into Boot Memory

With a little logic between the ADSP-2115 and boot memory, it is possible to map PM and/or DM into unused portions of the boot memory. Although this data is only 8-bits wide, it can store other data such as function look-up tables and/or data constants.

To map PM and/or DM into unused portions of the boot memory, both the boot memory select pin (BMSL) and data or program memory select (PMSL) pins must logically select different sections of the boot memory.

In addition, the 14 address lines from the DSP must connect directly to the 14 least significant address lines of the boot memory. Less than 14 address lines can be used to allocate a smaller block of PM or DM but they should be contiguously connected on both the DSP and boot memory. If no memory-efficient allocation scheme is used this method is not necessary (page packing). If this scheme is used, additional logic is needed to allow BM, DM and PM accesses to function correctly.

### Modifying the Boot Memory Image file

If you alter the configuration of the address lines between the DSP and the boot memory, the ASCII boot memory image file (\*.bnm) created by the splitter must also be modified to reflect these changes. In many cases a simple text editor macro can perform all of the required modifications. Below are descriptions of the various boot memory image file modifications required for the various schemes described throughout this document.

## Removing address lines to 'pack' boot pages next to each other:

The following switch must be used in the splitter's command line to set the 'boot boundary' between pages.

- For boot pages 4096 bytes apart (DSP's with 1Kwords of program memory):  
-bb 1024
- For boot pages 2048 bytes apart (for DSP's with 512 words of program memory):  
-bb 512

(although this is not listed as an option for the splitter, it will work)

## Using Multiple Boot-Page 'Banks'

To use Multiple Boot-Page 'Banks', each bank of boot-pages is generated separately by the splitter. Then the \*.BNM generated by the splitter must be edited manually (see Tables 2 and 3 for a description of both Intel Hex and Motorola S data formats). Using a text editor 1) load each .BNM file and 2) patch them together. The address fields of each .bnm file must be modified to reflect the new location in boot memory (except for bank 0 which always begins at zero).

## Mapping Program and Data Memory into Boot Memory Space

To place data into the data and program memory mapped areas of boot memory, the .bnm file created by the splitter must be edited manually with a text editor. The following steps describe this procedure:

1. Determine the boot memory address where the data begins
2. Create an addendum containing the data and paste it onto the end of the .bnm file
3. Save the original

The following is an example demonstrating this process:

The original bnm file created by the splitter in Motorola-S format:

```
S0030000FC
S125000018062034219A00FF...
S9030000FC
```

Original Data to be stored in memory mapped program memory follows:

```
00, 01, 03, 04, 06, 07, 08, 0A, 0C, 0E...
```

The following data is put into Motorola-S format starting at address 4800:

```
S1254800000103040607080A0C0E...
```

Insert the following into the original bnm file:

```
S0030000FC
S125000018062034219A00FF...
S1254800000103040607080A0C0E...
S9030000FC
```

In this example system, PM is mapped to the boot memory address 0x4800 (see Figure 1). A sequence of 8-bit values located in this range must be manually inserted into the .bnm file.

## Describing An Example System

The example system described here uses an ADSP-2115 with 512 bytes of PM, a 512 Kbit boot memory device and a programmable logic device.

The system has 2 banks of 8 boot pages, each 2048 bytes long (since there is only 512 program memory words to load) and 2 x 14K banks of 8-bit wide PM (See Figure 1).

Because you need only 2048 bytes per boot page pins A0-A10 of the DSP cycle through the 2048 locations of each boot page. To select the boot pages, connect pins A13,D22 and D23 of the DSP to pins A11-A13 of the boot memory (only while accessing boot memory). This packs the boot pages next to each other so they are all 2048 bytes apart (vs. 8192 bytes apart).

Pin A14 of the boot memory device is used to select access of the boot pages or the 8-bit PM in boot memory.

Pin A15 of the boot memory device can be set high or low to yield two 'banks' of boot page and PM blocks. In the example system, pin A15 is connected to a memory-mapped D flip-flop located in data memory space providing a total of 16 boot pages in the system. To load a page from bank 1 into memory (after page 0 has been loaded into PM) set A15 to a logical high by writing to the memory-mapped flip-flop and initiate the automated boot-page loading procedure.

Below is a set of logic equations used in a programmable logic device that is between the DSP and the boot memory device:

Note: any signals with a ' / ' in front are negated.

If an input or output signal has a ' / ' in front, it is negated when the signal enters or leaves the programmable logic device)

**inputs:** A11, A12, A13 ; address lines from the DSP

/DMS, /PMS ; negated select lines from DSP

D22, D23 ; data lines from the DSP

**output:** EA11, EA12, EA13, EA14 ; A11-A14 of boot memory device

/ES ; boot memory select

**equations:**

$$EA11 = (A13 * BMS) + (A11 * PMS);$$

$$EA12 = (D22 * BMS) + (A12 * PMS);$$

$$EA13 = (D23 * BMS) + (A13 * PMS);$$

$$EA14 = BMS + /PMS;$$

**Intel Hex File Format**

The 8-bit Intel Hex File Format is a printable ASCII format consisting of one or more data records followed by an end of file record. Each record consists of one line of information. Data records may appear in any order. Address and data values are represented as 2 or 4 hexadecimal digit values.

| Field | Definition  |
|-------|---|
| LL    | Length field–Number of data bytes   |
| AAAA  | Address field–Address of first byte   |
| RR    | Record type field–00 for data and 01 for end of record.                                     |
| DD    | Data field  |
| CC    | Checksum field–One's complement of length, address, record type and data fields modulo 256. |

**Table 2 Intel Hex Record Format :**

Example:

:06010000010203040506E4

:00000001FF

**Motorola S-Record File Format**

The 8-bit Motorola S-Record File Format is a printable ASCII format consisting of an optional header record, and one or more data records followed by an end of file record. Data records may appear in any order. Values are represented as 2 or 4 hexadecimal digit values.

| Field | Definition   |
|-------|--|
| S     | Start of record mark (letter S).   |
| N     | Record type field–0 for header, 1 for data, 9 for end of record. All other record types are ignored. |
| LL    | Length field–Number of bytes to follow.  |
| AAAA  | Address field–Address of first byte.   |
| DD    | Data field   |
| CC    | Checksum field–One's complement of the length, address and data fields modulo 256 - 1.               |

**Table 3 Motorola S-Record Format :**

Example:

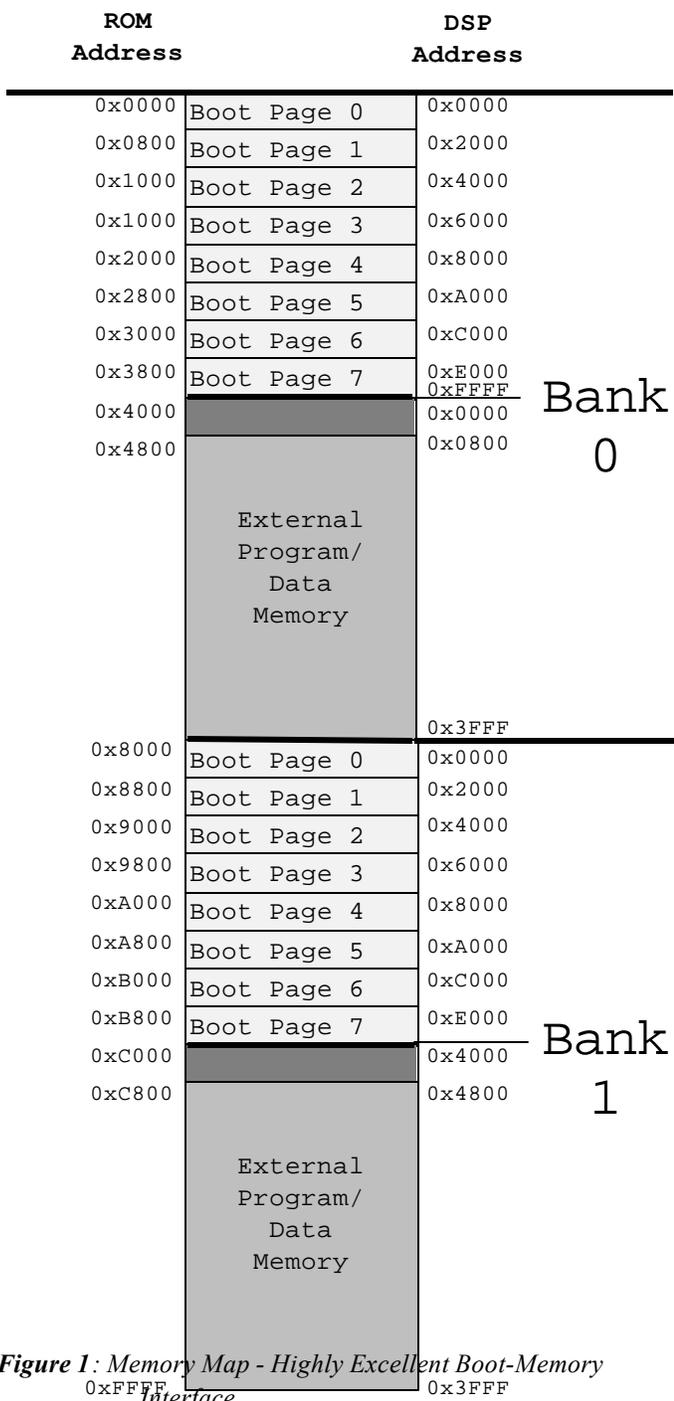
S0030000FC

S1090100010203040506E0

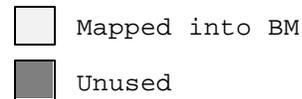
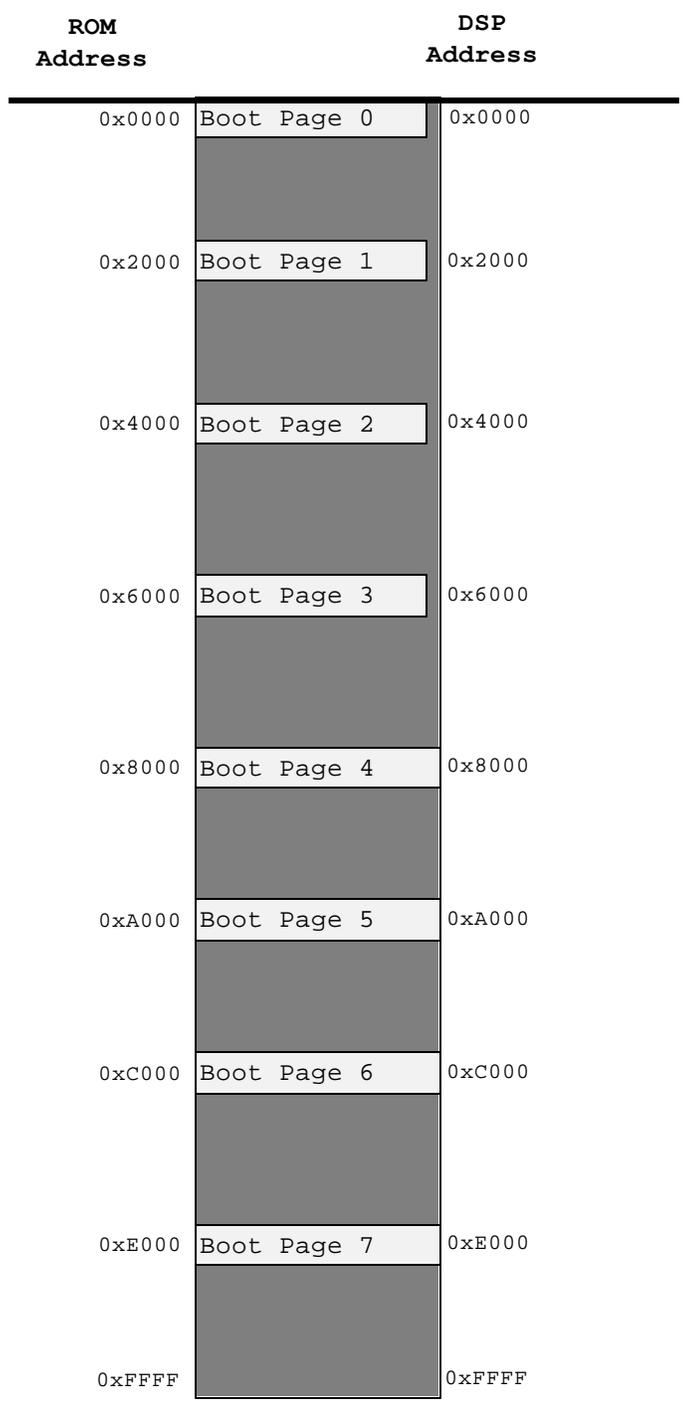
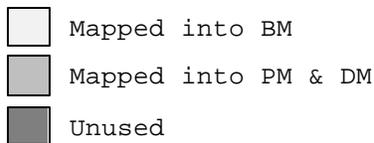
S9030000FC

Note: The first line in the above example Motorola S-Record header record. The second line is a data record addressed at location 100 with data values 1 to 6. The third line is the end of file record.

# Memory Maps For 2 ADSP 2115 Systems (512 words of program memory)



**Figure 1: Memory Map - Highly Excellent Boot-Memory Interface**



**Figure 2: Memory Map - Basic Boot Memory Interface with 2048 byte boot-pages**