Application Report
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TMS320F28004x Boot Features and Configurations

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ABSTRACT

As C2000™ devices have advanced in terms of available peripherals, larger memories, pin count and other options, the startup boot code has also been enhanced along with it. When it comes to the boot options available on a device, they always have to be designed to balance flexibility in terms of customization as well as the ease of use by the developer. From C2000 device-to-device, these new features and options are not always clearly highlighted in comparison to older devices. Any new boot features are developed with an intended purpose in mind that may not be clear when coming from an older device. This application report includes details beyond what boot code does but actually how these features have been enhanced device-to-device and how to best take advantage of them in an application.

Contents

1 Introduction 2
2 Features and Configurations 2
3 Recommended Boot Configurations 5
4 How to Configure Boot Options 5
5 References 5

List of Tables

1 Boot Pin GPIO Selection Comparison 2
2 Number of Boot Pins Comparison 3
3 Default Boot Options Table Comparison 3
4 Boot Selection Table Comparison 4
5 Expanded Boot Mode Options Comparison 5
6 Recommended Example Boot Configurations 5

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1 Introduction

With devices growing in available memory, peripherals, and pin options, the need to enhance and allow further boot configurations is critical to developers. The boot mode options provided on the device drives the development strategy used to guarantee the device has the flexibility needed for all stages of development. Although code could be placed in flash to run custom kernels, this uses valuable flash memory space and adds additional delay before running the main application. C2000 devices over the years have strived toward a more configurable, less demanding boot flow by reducing the number of boot mode selection pins from 4 to 2 as well as adding some additional peripheral bootloader general-purpose input/output (GPIO) pin mux options. Still, these limitations remain regarding the required GPIOs, bootable addresses in flash, and only being able to program 1 custom boot mode option in the default boot mode selection table. This application report is here to not only detail how these customizable options have changed on various C2000 devices, but also explain how the new boot options on F28004x devices aim to solve all these issues leading to a much more customizable, flexible device.The following sections will cover several aspects of boot customizations now possible on F28004x. One being the customization of how many boot mode select pins are allocated on the device, which allows for such scenarios where 0 boot mode select pins are used, if desired. Additionally, the boot mode select pin GPIOs are configurable and it is possible to create a fully user defined default boot mode selection table using a greater defined set of available boot modes.

For more details regarding boot up flow and the referenced configurable boot memory locations, see the device-specific reference guides and technical reference manuals (TRM):

- *TMS320x2833x, 2823x Boot ROM Reference Guide*
- *TMS320x2802x Piccolo Boot ROM Reference Guide*
- *TMS320F2837xD Dual-Core Delfino Microcontrollers Technical Reference Manual*
- *TMS320F2837xS Delfino Microcontrollers Technical Reference Manual*
- *TMS320F2807x Piccolo Microcontrollers Technical Reference Manual*
- *TMS320F28004x Piccolo Microcontrollers Technical Reference Manual*

2 Features and Configurations

The complexity and flexibility of C2000 boot configurations have scaled as devices evolved. The latest enhanced features and options for specific boot configurations starting on F28004x devices now bring C2000 to a whole new level of customization and flexibility. The following sections will highlight and describe these new options. Additionally, a comparison is provided to show how such customizations were handled on past C2000 devices.

2.1 Selecting Boot Mode GPIOs

All the latest C2000 devices use a defined set of GPIOs to allow for boot mode selection upon device power-on or reset. This is accomplished by the boot code decoding the state, whether pulled high or low, of the GPIOs. Once decoded, the interpreted value is used as an index to select which boot mode from the boot mode selection table should be run. The GPIOs used as boot mode select pins have typically been locked to their default GPIO. Starting with the Delfino F2837xD devices and carried over to F28004x devices, the GPIOs used as boot mode select pins are now configurable. On F28004x, writing to the BOOTPIN_CONFIG memory location in user-configurable dual code security module (DCSM) OTP allows for all three of the possible boot mode select pins to be set to almost any GPIO available on the device. Devices are no longer locked to the factory default GPIOs, which allows for a greater flexibility in terms of pin usage.

Table 1. Boot Pin GPIO Selection Comparison

Device	Boot Pin GPIO Custom Selection
F2833x	No, must use default boot mode selection GPIOs
F2802x	No, must use default boot mode selection GPIOs
F2806x	No, must use default boot mode selection GPIOs
F2837xD/F2837xS/F2807x	Yes, can set which GPIOs to use as boot pins
F28004x	Yes, can set which GPIOs to use as boot pins

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2.2 Configure Number of Boot Mode Select Pins

C2000 devices have not only required a certain set of GPIOs to use as boot mode select pins, but a specified number of pins themselves. The number of boot mode select pins used either expands or restricts the available boot modes selectable in the boot table. If there are four boot mode select pins used, there can be up to 16 boot options selectable, but if only two boot mode select pins are used then only four boot options are selectable. On F28004x devices, the factory default setting is two boot mode select pins but the number of pins can be customized to support as many as three pins and as few as 0 pins. Using options such as 0 boot mode select pins, provides only a single boot mode to be selected but also frees up the other pins to be repurposed. If many boot modes are required for various scenarios, then using three pins will allow for selecting between eight possible boot choices. Disabling any particular boot mode selection pin uses the same BOOTPIN_CONFIG memory location as when changing the GPIO number used except now a value of “0xFF” is written to disable that specified pin.

Table 2. Number of Boot Pins Comparison

Device	Number of Boot Pins Customization
F2833x	No, must use 4 GPIOs for boot pins
F2802x	No, must use 2 GPIOs for boot pins
F2806x	No, must use 2 GPIOs for boot pins
F2837xD/F2837xS/F2807x	Yes, must use 2 GPIOs for boot pins
F28004x	Yes, can set how many boot pins are used (0 to 3)

2.3 Customizing the Boot Selection Table

Each C2000 device has a factory set default boot selection table that contains boot mode options available on an unprogrammed device. The default number of boot mode selection pins determines how many options are available in the default table. The latest devices use 2 boot mode selection pins and hence have 4 default boot modes selectable in the table.

Table 3. Default Boot Options Table Comparison

Device	Default Boot Table Options (unprogrammed device)
F2833x	0. SCI Boot (No ADC calibration)
	1. RAM Boot (No ADC calibration)
	2. Flash Boot (No ADC calibration)
	3. Check Boot (loop) mode
	4. RAM Boot
	5. Parallel XINTF Boot
	6. Parallel I/O
	7. OTP Boot
	8. XINTF x32 Boot
	9. XINTF x16 Boot
	10. McBSP Boot
	11. CAN Boot
	12. I2C Boot
	13. SPI Boot
	14. SCI Boot
	15. Flash Boot
F2802x	0. Parallel I/O
	1. SCI Boot
	2. Wait Boot
	3. Get Boot Mode / Flash
F2806x	0. Parallel I/O
	1. SCI Boot

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Table 3. Default Boot Options Table Comparison (continued)

Device	Default Boot Table Options (unprogrammed device)
	2. Wait Boot
	3. Get Boot Mode / Flash
F2837xD/F2837xS/F2807x	0. Parallel I/O
	1. SCI Boot
	2. Wait Boot
	3. Get Boot Mode / Flash
F28004x	0. Parallel I/O
	1. SCI/Wait Boot
	2. CAN Boot
	3. Flash Boot

Previous to F28004x devices, the 4th boot mode entry in the default boot table was programmable to whichever boot mode is required for the application. Now on F28004x, when programmed, the whole boot mode selection table is customizable. Depending on the number of boot mode selection pins enabled on the device, the custom boot selection table can have 1, 2, 4, or 8 boot mode options available. This custom table replaces the default factory table, so instead of parallel IO, for example, tied to boot option 0, this can now be set to any boot mode such as flash or CAN boot. This table is setup by configuring the 64-bit BOOTDEF memory location in user-configurable DCSM OTP. Each byte represents a specified boot mode.

Table 4. Boot Selection Table Comparison

Device	Number of Boot Pins Customization
F2833x	Not customizable, the table is locked to the factory default.
F2802x	Semi-customizable, the 4th entry in the boot table (Get mode) can be programmed to a specific boot mode
F2806x	Semi-customizable, the 4th entry in the boot table (Get mode) can be programmed to a specific boot mode
F2837xD/F2837xS/F2807x	Semi-customizable, the 4th entry in the boot table (Get mode) can be programmed to a specific boot mode
F28004x	Fully customizable, all boot options in the boot table can be programmed to whichever boot mode with the number of boot options available corresponding to the number of boot GPIOs used

2.4 Using Expanded Boot Options

When selecting boot modes, the memory addresses that they branch to upon booting or GPIOs used as part of a bootloader are predefined in ROM. This limits actions such as what address in memory flash boot will branch to or what GPIO muxing is available for SCI boot. Beginning with F2837xD devices, some additional peripheral GPIO mux options were provided to add more flexibility to the GPIOs used as part of the application. On F28004x, more of these expanded boot options have been added versus any other previous device. This includes 4 address options when booting to flash and multiple GPIO mux combinations for bootloader peripherals such as SCI, CAN, SPI, and I2C. Using the expanded boot options is no different than setting any other boot mode in the custom table. First find the boot mode option with the associated value in the GPIO assignments section of the TRM and then set it in the 64-bit BOOTDEF memory location in user-configurable DCSM OTP.

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Table 5. Expanded Boot Mode Options Comparison

Device	Number of Boot Pins Customization
F2833x	None, no additional flash entry addresses or peripheral GPIO muxing options
F2802x	None, no additional flash entry addresses or peripheral GPIO muxing options
F2806x	None, no additional flash entry addresses or peripheral GPIO muxing options
F2837xD/F2837xS/F2807x	Limited options, a few alternative peripheral GPIOs muxing options available. No alternative flash entry addresses.
F28004x	Yes, multiple flash entry address options and several GPIO muxing options available for SCI, CAN, SPI, and I2C peripherals.

3 Recommended Boot Configurations

With the latest boot enhancements on F28004x, the customizations now available allow for some specific boot scenarios to be setup. These range from using no boot mode select pins to using all 3 pins.

Table 6. Recommended Example Boot Configurations

Scenario	Number of Pins Used	Boot Mode Table Options
Zero boot pins	0	0. Flash Boot
Firmware upgrade	1	0. Flash Boot
		1. SCI/Any bootloader
Multi-function/flexible Device	3	0. Flash Boot
		1. Flash Boot (alternate address)
		2. Flash Boot (alternate address)
		3. Flash Boot (alternate address)
		4. SCI/Any bootloader
		5. CAN/Any bootloader
		6. I2C/Any bootloader
		7. SCI Alternative/Any bootloader

4 How to Configure Boot Options

For more details on how to configure these custom boot options, see F28004x TRM.

For an example on how to configure boot pins, a custom boot table, and use expanded boot options, see the *boot_ex2_customBootConfig* project under F28004x in C2000Ware.

5 References

- *TMS320x2833x, 2823x Boot ROM Reference Guide*
- *TMS320x2802x Piccolo Boot ROM Reference Guide*
- *TMS320F2837xD Dual-Core Delfino Microcontrollers Technical Reference Manual*
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