NXP Semiconductors
Application Note

Document Number: AN5203
Rev. 1.0, 7/2016

MC33816 vs. PT2000

Analog and software differences

1 Introduction

MC33816 and PT2000 are programmable solenoid controllers used to drive external N Channel MOSFETs, and are mainly used to drive direct fuel injectors and valves. They provide a flexible solution for MOSFET gate drives with a versatile control and optimized latency time. Gate drive, diagnosis, and protection are managed through independent microcores.

This application note examines all differences between the MC33816 and the PT2000.

NXP analog ICs are manufactured using the SMARTMOS process, a combinational BiCMOS manufacturing flow integrating precision analog, power functions, and dense CMOS logic together on a single cost-effective die.

Contents

2 Summary table

Table 1. Difference summary between MC33816 and PT2000

	MC33816	MC33PT2000
Typical application	4, 6 cylinder	3,4, and 6 cylinders
Number of bank	2	3
Number of high-side pre-drivers	5	7
Number of low-side pre-drivers	7	8
Number of current sense channels	4	6
Number of programmable cores	4	6
Number of diagnostic thresholds	8	12
Analog monitoring (OAx)	2	3
DCDC boost modes	PWM, Hysteretic	PWM, Hysteretic, Resonant
Microcore programming language	97% compatibility	
	Assembler	Assembler
Maximum Microcore CLK Frequency	6.0 MHz	12 MHz
I/O 36 V short complaint	No	Yes
LBIST	No	Yes
Dedicated safety pin/ISO26262	No	Yes
End of injection detection (EOI)	No	Yes
Package	LQFP-64	LQFP-80
Product status	Released to production	Samples available, 1Q 2018 Production

3 Analog differences

This chapter details some of the features mentioned in Table 1. Differences such as the number of high-sides, low-sides, and microcores, are not described in detail. End of injection detection is only on the PT2000 and details of this function can be requested through nxp.com by downloading the AN5071 (NDA required).

3.1 Current sense (VSENSEP/N)

As described previously, the MC33816 has four current sense for monitoring, three general purpose current sense, and one dedicated to DCDC. The PT2000 has six total current sense, four are general purpose and two which can be used for DCDC.

On both devices, DCDC current sense can be used as general purpose. The only difference between DCDC current and general purpose is the number of internal comparators.

DCDC current includes three comparators:

- High threshold comparator: used for Hysteretic control or general purpose
- Low threshold comparator: used for Hysteretic control
- Negative threshold comparator (to detect overcurrent during Boost phase)

Table 2. Current sense description

Current sense	MC33816	PT2000
$V_{SENSEP/N}$ 1	General Purpose Current Sense	General Purpose Current Sense
$V_{SENSEP/N}$ 2	General Purpose Current Sense	General Purpose Current Sense
$V_{SENSEP/N}$ 3	General Purpose Current Sense	General Purpose Current Sense
$V_{SENSEP/N}$ 4	DCDC Current Sense	General Purpose Current Sense
$V_{SENSEP/N}$ 5		DCDC Current Sense
$V_{SENSEP/N}$ 6		DCDC Current Sense

3.2 Diagnostic V_{DS} and V_{SRC} monitor

3.2.1 V_{DS} and V_{SRC} thresholds

The number of V_{DS} and V_{SRC} monitors for high-side and low-side threshold on the PT2000 was improved to use a very low $R_{DS(on)}$ external MOSFET and still have a good detectability.

Table 3. V_{DS} and V_{SRC} monitor threshold selection

V_{DS}/V_{SRC} threshold	Threshold voltage (V)
0000	0.00
1001	0.10
1010	0.20
1011	0.30
1100	0.40
0001	0.50
0010	1.0
0011	1.5
0100	2.0
0101	2.5
0110	3.0
0111	3.5

3.2.2 DCDC low-side V_{DS} monitoring

The MC33816 DCDC low-side does not integrate V_{DS} monitoring. The DCDC LS7 and LS8 low sides on the PT2000 can be used for VDS monitoring for diagnostics purposes, but also for the new DCDC regulation mode called Resonant mode.

3.3 DCDC automatic mode regulation

The MC33816 includes two types of regulation for DCDC:

- **PWM mode:** Control of low-side is done manually by microcode, with a fixed frequency, for example
- **Hysteric mode**: This mode regulates the current inside the inductance between the two low and high thresholds to set current sense 7. The voltage regulation for V_{BOOST} is done manually by microcode

The PT2000 now includes the two previous modes and a new regulation meant to reduce switching losses:

- **Resonant mode**: this mode uses only the high current threshold set in current sense 7 or 8, and V_{DS} monitoring across the low side. If the V_{DS} monitors goes lower than 2.5 V, then the low-side is turned ON again and remains ON until the current target is reached. For better description refer to the PT2000 datasheet.

3.4 Safety/shut off path (DRVEN)

Both devices, the MC33816 and the PT2000, have a DRVEN pin to disable all high-side and low-side pre-drivers. The design of this feature on the PT2000 was implemented to ensure a high safety level. It is designed with a high level of independence, because there is a direct wire from this pin to the high-side pre-driver input, therefore the failure rate of this functionally is very low.

If any of the following failures occur, either the shut off path is still functional or the driver must be in a safe off state.

- Missing clock signal for the device digital core
- Missing supply voltage for the device digital core
- Missing supply voltage of level shifter
- Missing supply voltage (V_{BS}) of high-side pre-driver
- Single damaged pre-driver

Figure 1 shows differences between the MC33816 and the PT2000 using a simplified block diagram of a high-side pre-driver.

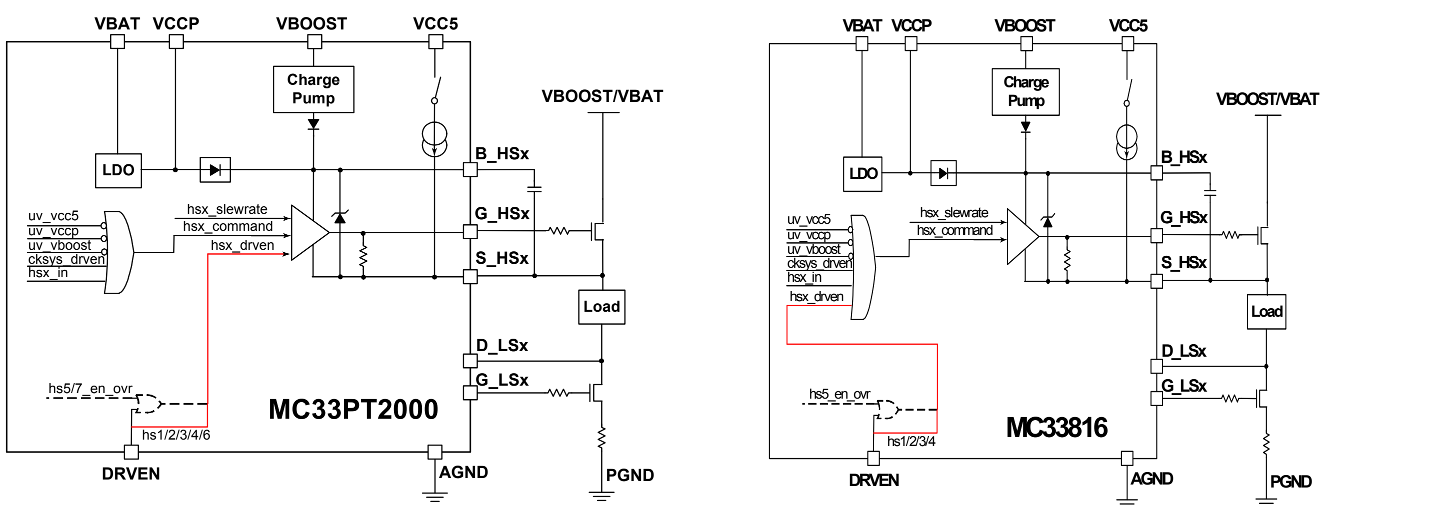

Figure 1. Comparison between the MC33816 and the PT2000 safety path

3.5 Analog output (OAx)

Since the PT2000 has more current sense inputs, the number of analog outputs were increased by one to be able to monitor current of the third bank. The diagrams in Figure 2 compares devices.

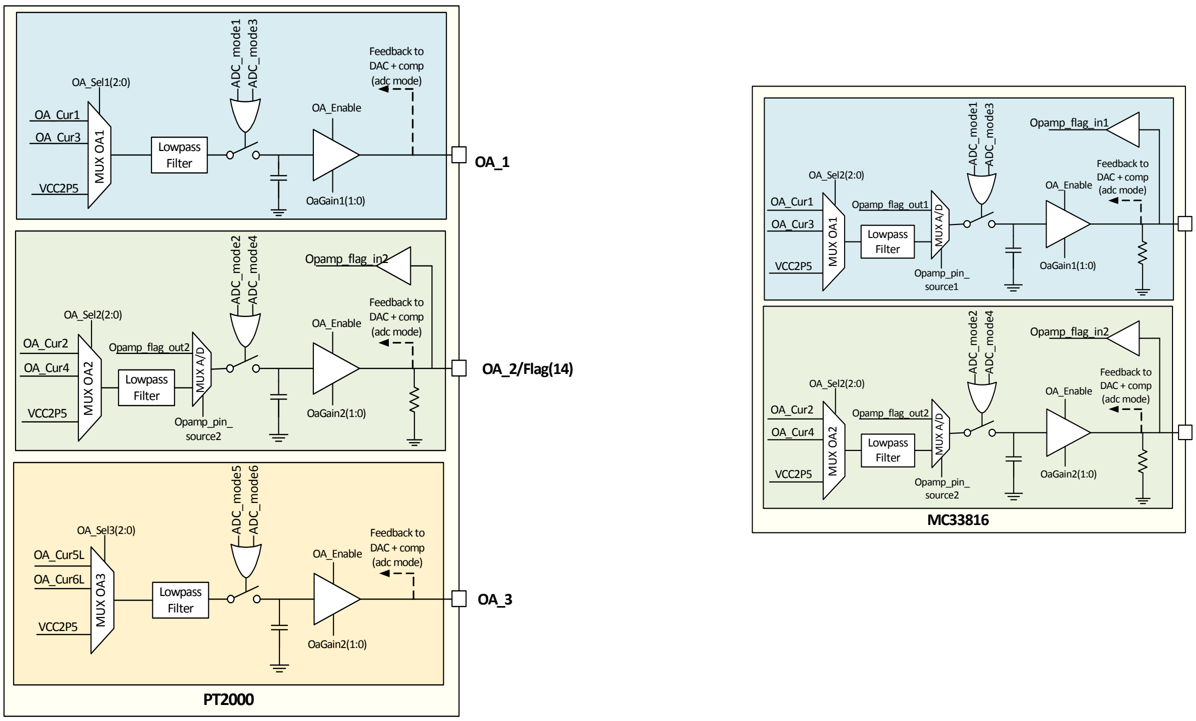

Figure 2. OA multiplexer on the MC33816 and the PT2000

When designing the ECU, it is important to look at the OA multiplexer, especially if full overlap is needed. For example, if the MCU requires access to current going through each bank simultaneously, this option can be chosen:

- BANK1 -> Current Sense 1 and/or 3
- BANK2 -> Current Sense 2 and/or 4
- BANK3 -> Current Sense 5 and/or 6

OA1 and OA2 on the MC33816 have the option to be used as a flag; the PT2000 only offers this possibility on OA2.

3.6 Battery voltage monitor

The MC33816 and the PT2000 have the potential to monitor Boost voltage using the BOOST pin. The battery monitoring feature is only on the PT2000. Battery voltage is divided by 16 using the R divider and an internal ADC sends the voltage level to the SPI register.

The battery voltage threshold can be calculated using the V_{BAT} = (DAC_VALUE * 39.06 mV) x 16 formula.

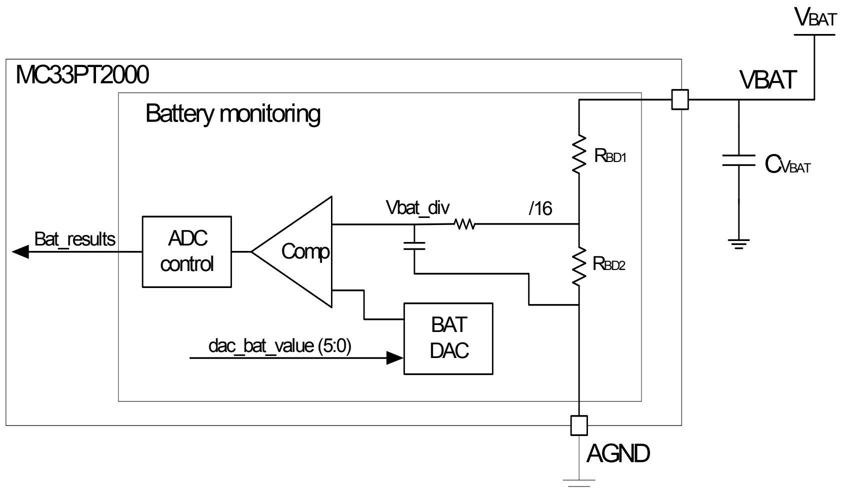

Figure 3. Battery voltage monitoring

4 Software differences

4.1 Microcode instructions

Programming the PT2000 is done using 96 instructions compared to 93 on the MC33816. All MC33816 instructions are included in the PT2000, making device compatibility around 97%.

The three new microcode instructions are:

- slocdac: The instruction changes the value of the “other channel” config bit in the dac_rxtx_cr_config register
- sl56dac: The instruction changes the value of the “dac56” config bit in the dac_rxtx_cr_config register
- swi: Enables or disables all SW interrupts from the reqi instruction and from start edges for a sequencer

Even if the instruction set is similar, the number of parameters can differ. For example, the cwer/cwef instructions used to configure wait table includes six rows on the PT2000 compared to five on the MC33816. Similar comments are for the sto/stos output control instruction, since on the PT2000 there are seven high-sides and eight low-sides. The number offers more possible parameters (hs1 to hs7 and ls1 to ls8).

4.1.1 DCDC instructions

Since DCDC current sense is different between the MC33816 and the PT2000, instruction parameters change.

- The MC33816 current sense and DAC DCDC parameters are: cur4l, cur4h, cur4n, dac4l, dac4h, and dac4h4n.
- The PT2000 current sense and DAC DCDC parameters are: cur56l, cur56h, cur56n, dac5l, dac6l, dac5h, dac6h, and dac56h56n. Selection between current sense 5 and 6 on the PT2000 is done using SPI registers Vds7_dcdc_config (182h) & Vds8_dcdc_config (183h)

Since two low-sides can be used for DCDC on the PT2000, the instruction to control DCDC automatically on the PT2000 (stdcctl) affects the low-side pre-driver, which is set as shortcut 2 of the sequencer. This shortcut has to be set to LS7 or LS8 to select the low-side (refer to datasheet for more details).

4.2 Dual microcore arbitrer

To guarantee access to the CRAM in dual microcore mode, the MC33816 requires a prescaler bigger than three, meaning the maximum microcore CLK frequency is 6.0 MHz. Memory access on the PT2000 is improved for maximum CLK frequency. For dual mode, the frequency is 12 MHz.

Table 4. Code RAM access sequence (dual microcore mode)

Ck_per	flash_enable	T0	T1	T2	T3	Teven	Todd	Cycle stealing when uc0/1 are in wait
1	1	uc0	uc1					CHKSM
1	0	SPI r/w	SPI r/w					
2	1	uc0	uc1	CHKSM				CHKSM
2	0	SPI r/w	SPI r/w	SPI r/w				
3	1	uc0	uc1	CHKSM	SPI r	-	-	CHKSM
3	0	SPI r/w	SPI r/w	SPI r/w	SPI r/w	-	-	
4	1	uc0	uc1	CHKSM	SPI r	CHKSM	SPI r	CHKSM
4	0	SPI r/w	SPI r/w	SPI r/w	SPI r/w	SPI r/w	SPI r/w	

The PT2000 can be used as a dual sequencer with a ck_per = 1, which means with a microcode clock at 12 MHz. However, some restrictions apply to the DRAM access (refer to datasheet).

4.3 Freewheeling flags

Both devices have freewheeling capability between the high-side command and the freewheeling low-side. The MC33816 has the following configurations possible:

Table 5. MC33816 automatic freewheeling link

Freewheeling output	Related high-side
LS5	HS1
LS6	HS2
LS7	HS3
HS5	HS4
LS4	HS5

The PT2000 offers two possibilities of either a freewheeling with a low-side or with a flag pin to control external a dummy low-side driver. Selection between the LS or flag pin for the freewheeling is achieved due to the SPI register Fw_link (169h).

.

Table 6. PT2000 automatic freewheeling link

Freewheeling pre-driver output	Related pre-driver high-side
LS1	HS1
LS2	HS2
LS3	HS3
LS4	HS4
LS5	HS5
LS6	HS6
LS7	HS7
Flag0	HS4
Flag1	HS5
Flag2	HS6
Flag3	HS7

4.4 LBIST

Both devices have a built-in self test (BIST) for the memory (MBIST for CRAM and DRAM). The PT2000 is also able to check the integrity of the logic core through LBIST. The LBIST on the PT2000 starts by writing the LBIST password (0666h) to the BIST register. The overall LBIST operation takes about 32 ms (at 24 MHz) to complete. The coverage of the LBIST is > 92%.

5 References

Description	URL
MC33PT2000 Data Sheet	http://www.nxp.com/files/analog/doc/data_sheet/MC33PT2000.pdf
MC33816 Data Sheet	http://www.nxp.com/files/analog/doc/data_sheet/MC33816.pdf
End of Injection detection - Application Note	https://www.nxp.com/webapp/Download?colCode=AN5071
MC33PT2000 Programming Guide and Instruction Set	http://www.nxp.com/files/analog/doc/user_guide/PT2000SWUG.pdf

6 Revision history

Revision	Date	Description of changes
1.0	10/2015	• Initial release
	11/2015	• Updated Table 1 title
	7/2016	• Updated to NXP document form and style

How to Reach Us:

Home Page:
NXP.com

Web Support:
http://www.nxp.com/support

Document Number: AN5203
Rev. 1.0
7/2016