

PWM →

# Line Tracer 07

- Timer A -

**This lecture is based on**

- Timers

# **1. Timer A**

# Timer A

## Advanced Timer vs SysTick Timer

- SysTick timer only provides simple features
- Timer A provides rich features (PWM, ...)

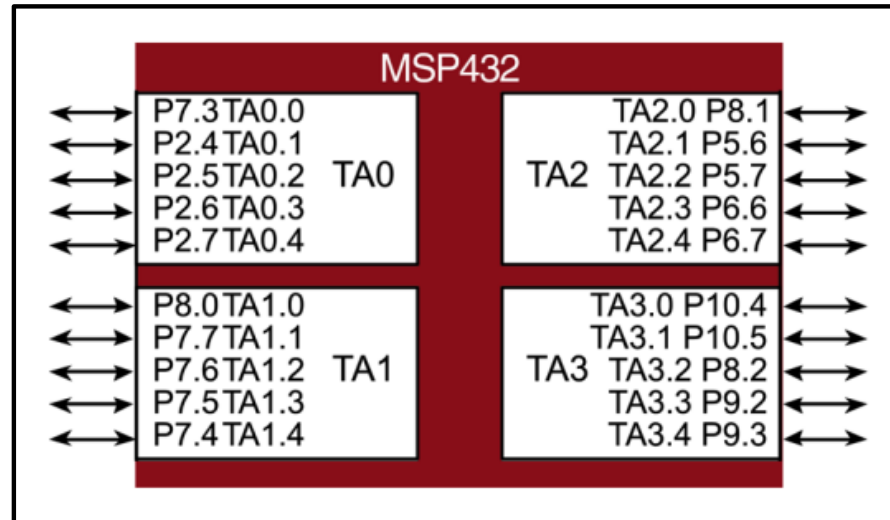
## What we're going to run

- Generate PWM using timer

# MSP432 Timer A

MSP432 Timer A consists of

- 4 Timers **TA0, TA1, TA2, TA3**
- Each timer has submodules



# Timer A Registers

	15-10	9-8	7-6	5-4	3	2	1	0	Name				
0.0000		TASSEL	ID	MC		TACLR	TAIE	TAIFG	TA0CTL				
	15-14	13-12	11	10	9	8	7-5	4	3	2	1	0	
0.0002	CM	CCIS	SCS	SCCI		CAP	OUTMOD	CCIE	CCI	OUT	COV	CCIFG	TA0CCTL0
0.0004	CM	CCIS	SCS	SCCI		CAP	OUTMOD	CCIE	CCI	OUT	COV	CCIFG	TA0CCTL1
0.0006	CM	CCIS	SCS	SCCI		CAP	OUTMOD	CCIE	CCI	OUT	COV	CCIFG	TA0CCTL2
0.0008	CM	CCIS	SCS	SCCI		CAP	OUTMOD	CCIE	CCI	OUT	COV	CCIFG	TA0CCTL3
0.000A	CM	CCIS	SCS	SCCI		CAP	OUTMOD	CCIE	CCI	OUT	COV	CCIFG	TA0CCTL4
0.000C	CM	CCIS	SCS	SCCI		CAP	OUTMOD	CCIE	CCI	OUT	COV	CCIFG	TA0CCTL5
0.000E	CM	CCIS	SCS	SCCI		CAP	OUTMOD	CCIE	CCI	OUT	COV	CCIFG	TA0CCTL6
	15-0												
0.0010	16-bit counter												TA0R
0.0012	16-bit Capture/Compare 0 Register												TA0CCR0
0.0014	16-bit Capture/Compare 1 Register												TA0CCR1
0.0016	16-bit Capture/Compare 2 Register												TA0CCR2
0.0018	16-bit Capture/Compare 3 Register												TA0CCR3
0.001A	16-bit Capture/Compare 4 Register												TA0CCR4
0.001C	16-bit Capture/Compare 5 Register												TA0CCR5
0.001E	16-bit Capture/Compare 6 Register												TA0CCR6
	15-3										2-0		
0.0020											TAIDEX		TA0EX0
	15-0												
0.002E	TAIV												TA0IV

# Timer A Register – CTL 각 비트의 의미

Table 17-4. TAxCTL Register Description				
Bit	Field	Type	Reset	Description
15-10	Reserved	RW	0h	Reserved
9-8	TASSEL	RW	0h	Timer_A clock source select 00b = TAxCLK 01b = ACLK 10b = SMCLK 11b = INCLK
7-6	ID	RW	0h	Input divider. These bits along with the TAIDEX bits select the divider for the input clock. 00b = /1 01b = /2 10b = /4 11b = /8
5-4	MC	RW	0h	Mode control. Setting MCx = 00h when Timer_A is not in use conserves power. 00b = Stop mode: Timer is halted 01b = Up mode: Timer counts up to TAxCCR0 10b = Continuous mode: Timer counts up to 0FFFFh 11b = Up/down mode: Timer counts up to TAxCCR0 then down to 0000h
3	Reserved	RW	0h	Reserved
2	TACLR	RW	0h	Timer_A clear. Setting this bit resets TAxR, the timer clock divider logic, and the count direction. The TACLR bit is automatically reset and is always read as zero.
1	TAIE	RW	0h	Timer_A interrupt enable. This bit enables the TAIFG interrupt request. 0b = Interrupt disabled 1b = Interrupt enabled
0	TAIFG	RW	0h	Timer_A interrupt flag 0b = No interrupt pending 1b = Interrupt pending

# Timer A Register – CCTL

Bit	Field	Type	Reset	Description
15-14	CM	RW	0h	Capture mode 00b = No capture 01b = Capture on rising edge 10b = Capture on falling edge 11b = Capture on both rising and falling edges
13-12	CCIS	RW	0h	Capture/compare input select. These bits select the TAxCCR0 input signal. See the device-specific data sheet for specific signal connections. 00b = CClxA 01b = CClxB 10b = GND 11b = VCC
11	SCS	RW	0h	Synchronize capture source. This bit is used to synchronize the capture input signal with the timer clock. 0b = Asynchronous capture 1b = Synchronous capture
10	SCCI	RW	0h	Synchronized capture/compare input. The selected CCI input signal is latched with the EQUx signal and can be read via this bit.
9	Reserved	R	0h	Reserved. Reads as 0.
8	CAP	RW	0h	Capture mode 0b = Compare mode 1b = Capture mode
7-5	OUTMOD	RW	0h	Output mode. Modes 2, 3, 6, and 7 are not useful for TAxCCR0 because EQUx = EQU0. 000b = OUT bit value 001b = Set 010b = Toggle/reset 011b = Set/reset 100b = Toggle 101b = Reset 110b = Toggle/set 111b = Reset/set
4	CCIE	RW	0h	Capture/compare interrupt enable. This bit enables the interrupt request of the corresponding CCIFG flag. 0b = Interrupt disabled 1b = Interrupt enabled
3	CCI	R	0h	Capture/compare input. The selected input signal can be read by this bit.
2	OUT	RW	0h	Output. For output mode 0, this bit directly controls the state of the output. 0b = Output low 1b = Output high

Bit	Field	Type	Reset	Description
1	COV	RW	0h	Capture overflow. This bit indicates a capture overflow occurred. COV must be reset with software. 0b = No capture overflow occurred 1b = Capture overflow occurred
0	CCIFG	RW	0h	Capture/compare interrupt flag 0b = No interrupt pending 1b = Interrupt pending



## Timer A Register – TAxEX0

**Table 17-9. TAxEX0 Register Description**

Bit	Field	Type	Reset	Description
15-3	Reserved	R	0h	Reserved. Reads as 0.
2-0	TAIDEX	RW	0h	Input divider expansion. These bits along with the ID bits select the divider for the input clock. 000b = Divide by 1 001b = Divide by 2 010b = Divide by 3 011b = Divide by 4 100b = Divide by 5 101b = Divide by 6 110b = Divide by 7 111b = Divide by 8

# Timer A Register – Output Modes

**Table 17-2. Output Modes**

OUTMODx	Mode	Description
000	Output	The output signal OUTn is defined by the OUT bit. The OUTn signal updates immediately when OUT is updated.
001	Set	The output is set when the timer <i>counts</i> to the TAxCCRn value. It remains set until a reset of the timer, or until another output mode is selected and affects the output.
010	Toggle/Reset	The output is toggled when the timer <i>counts</i> to the TAxCCRn value. It is reset when the timer <i>counts</i> to the TAxCCR0 value.
011	Set/Reset	The output is set when the timer <i>counts</i> to the TAxCCRn value. It is reset when the timer <i>counts</i> to the TAxCCR0 value.
100	Toggle	The output is toggled when the timer <i>counts</i> to the TAxCCRn value. The output period is double the timer period.
101	Reset	The output is reset when the timer <i>counts</i> to the TAxCCRn value. It remains reset until another output mode is selected and affects the output.
110	Toggle/Set	The output is toggled when the timer <i>counts</i> to the TAxCCRn value. It is set when the timer <i>counts</i> to the TAxCCR0 value.
111	Reset/Set	The output is reset when the timer <i>counts</i> to the TAxCCRn value. It is set when the timer <i>counts</i> to the TAxCCR0 value.

## **2. PWM Using Timer**

# PWM Using Timer

## Previous PWM Implementation

- We created PWM signal manually
- Hard to understand source code
- Nothing can be done during the delay

**Waste of Time !**

```
while(1) {  
    TurnOn_LED1()  
    Clock_Dealy1us(1)  
    TurnOff_LED()  
    Clock_Delay1us(9)  
}
```

**LED1 Brightness 10%**

**+**

```
while(1) {  
    TurnOn_LED2()  
    Clock_Dealy1us(8)  
    TurnOff_LED()  
    Clock_Delay1us(2)  
}
```

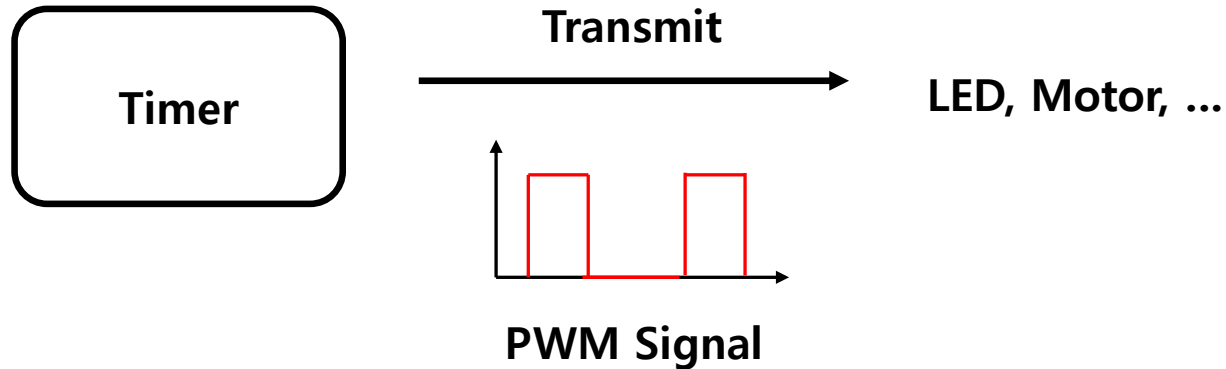
**LED2 Brightness 80%**

**= ?**

# PWM Using Timer

## PWM Using Timer

- Transmit the timer generated signal
- Timer takes care of everything!



# PWM Using Timer

## GPIO vs Alternative

- In GPIO, we have to deal with the relevant hardware ourselves  
(Turn Off/On LED, Read Switch, Generate PWM Signal ...)
- In Alternative Mode, the hardware does tasks such as generating PWM signals

```
void turn_on_led(int color) {  
    P2->OUT &= ~0x07;  
    P2->OUT |= color;  
}  
void turn_off_led() {  
    P2->OUT &= ~0x07;  
}
```

In GPIO, we delivered the signal by reading and writing on the relevant port (register) directly

# DC Motor Using PWM

초기화

```
void pwm_init34(uint16_t period, uint16_t duty3, uint16_t duty4) {  
    // CCR0 period  
    TIMER_A0->CCR[0] = period;  
  
    // divide by 1  
    TIMER_A0->EX0 = 0x0000;  
  
    // toggle/reset  
    TIMER_A0->CCTL[3] = 0x0040;  
    TIMER_A0->CCR[3] = duty3;  
    TIMER_A0->CCTL[4] = 0x0040;  
    TIMER_A0->CCR[4] = duty4;  
  
    // 0x200 -> SMCLK  
    // 0b1100 0000 -> input divider /8  
    // 0b0011 0000 -> up/down mode  
    TIMER_A0->CTL = 0x02F0;  
  
    // set alternative  
    P2->DIR |= 0xC0;  
    P2->SEL0 |= 0xC0;  
    P2->SEL1 &= ~0xC0;  
}
```

# DC Motor Using PWM

초기화

```
void motor_init(void) {
    P3->SEL0 &= ~0xC0;
    P3->SEL1 &= ~0xC0;           // 1) configure nSLPR & nSLPL as GPIO
    P3->DIR |= 0xC0;             // 2) make nSLPR & nSLPL as output
    P3->OUT &= ~0xC0;           // 3) output LOW

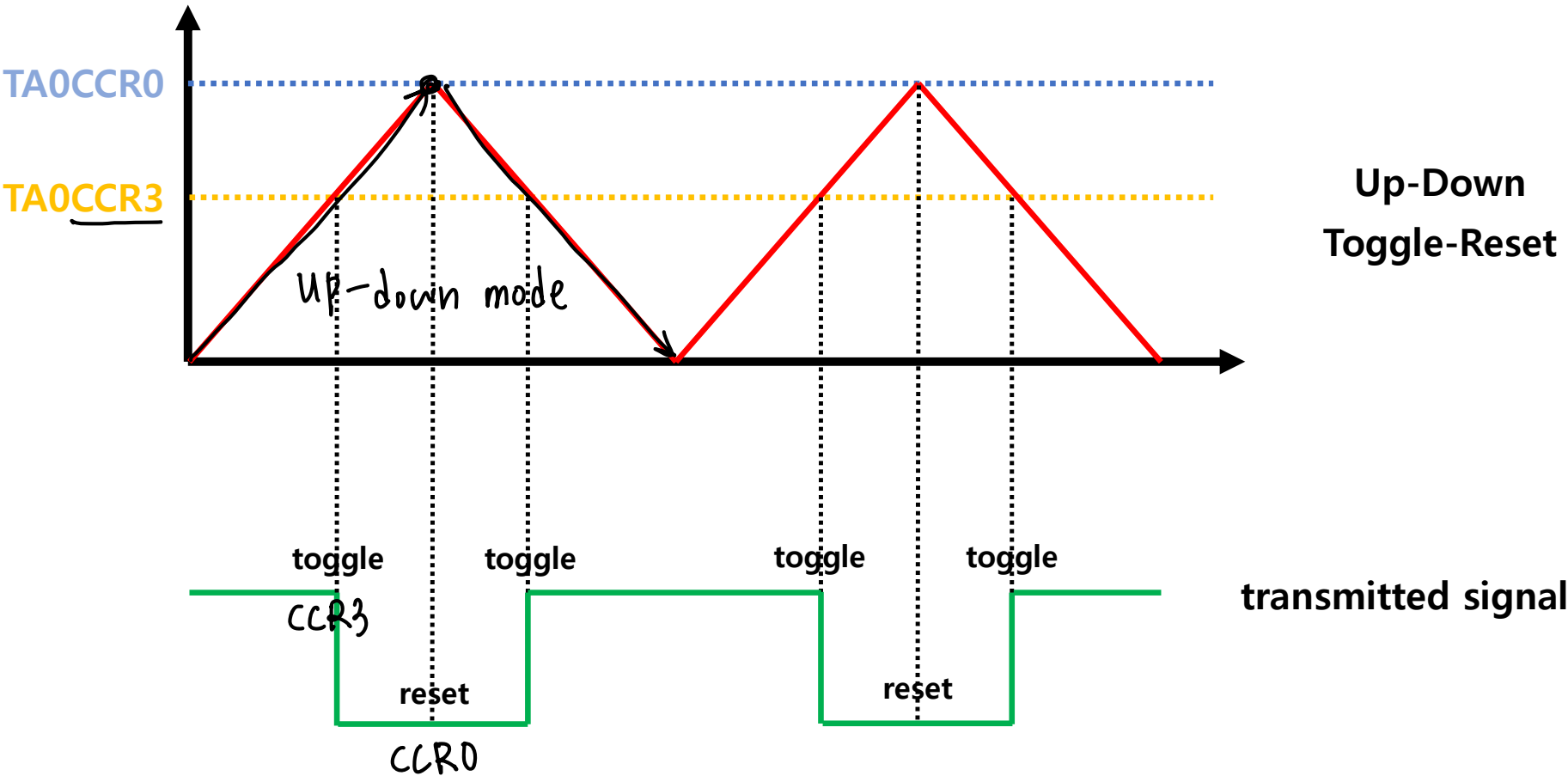
    P5->SEL0 &= ~0x30;
    P5->SEL1 &= ~0x30;           // 1) configure DIRR & DIRL as GPIO
    P5->DIR |= 0x30;             // 2) make DIRR & DIRL as output
    P5->OUT &= ~0x30;           // 3) output LOW

    P2->SEL0 &= ~0xC0;
    P2->SEL1 &= ~0xC0;           // 1) configure PWMR & PWML as GPIO
    P2->DIR |= 0xC0;             // 2) make PWMR & PWML as output
    P2->OUT &= ~0xC0;           // 3) output LOW

    pwm_init34(7500, 0, 0);
}
```

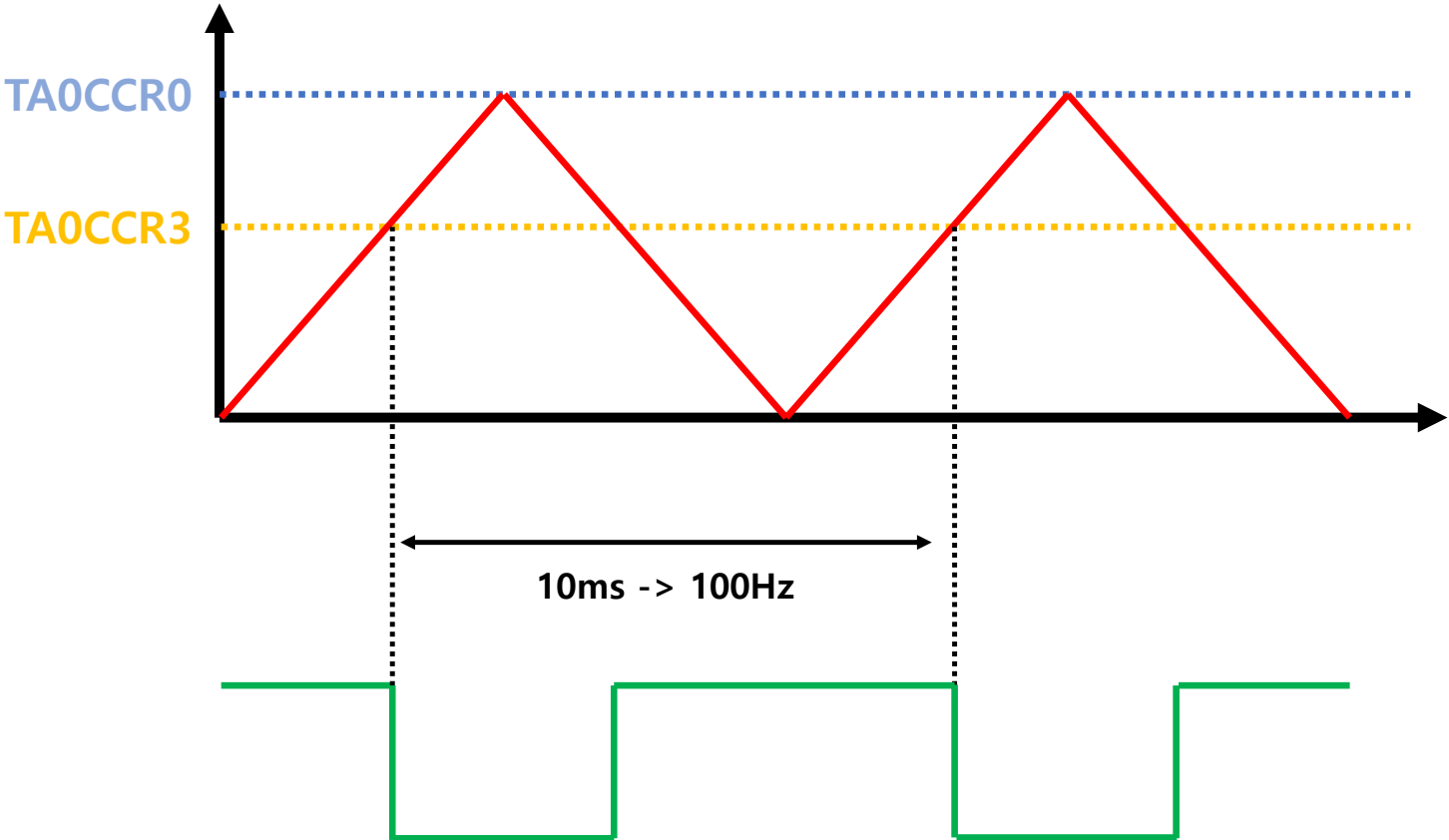


# How Do We Generate PWM Using Timer



# Timer Frequency

PWM 신호주기 설정



## Timer Frequency

$$\begin{aligned}\text{Timer Frequency} &= \text{Clock Source(SMCLK)} / 2^{\text{ID(Input Divider)}} / \text{TAIDX} \\ &= 12\text{MHz} / 1 / 8 \\ &= 1.5\text{MHz}\end{aligned}$$

$$100\text{Hz (PWM Frequency)} = \text{Timer Frequency} / (2 * \text{TA0CCR0})$$

$$\text{TA0CCR0} = 7500$$

# Set Pin Mode

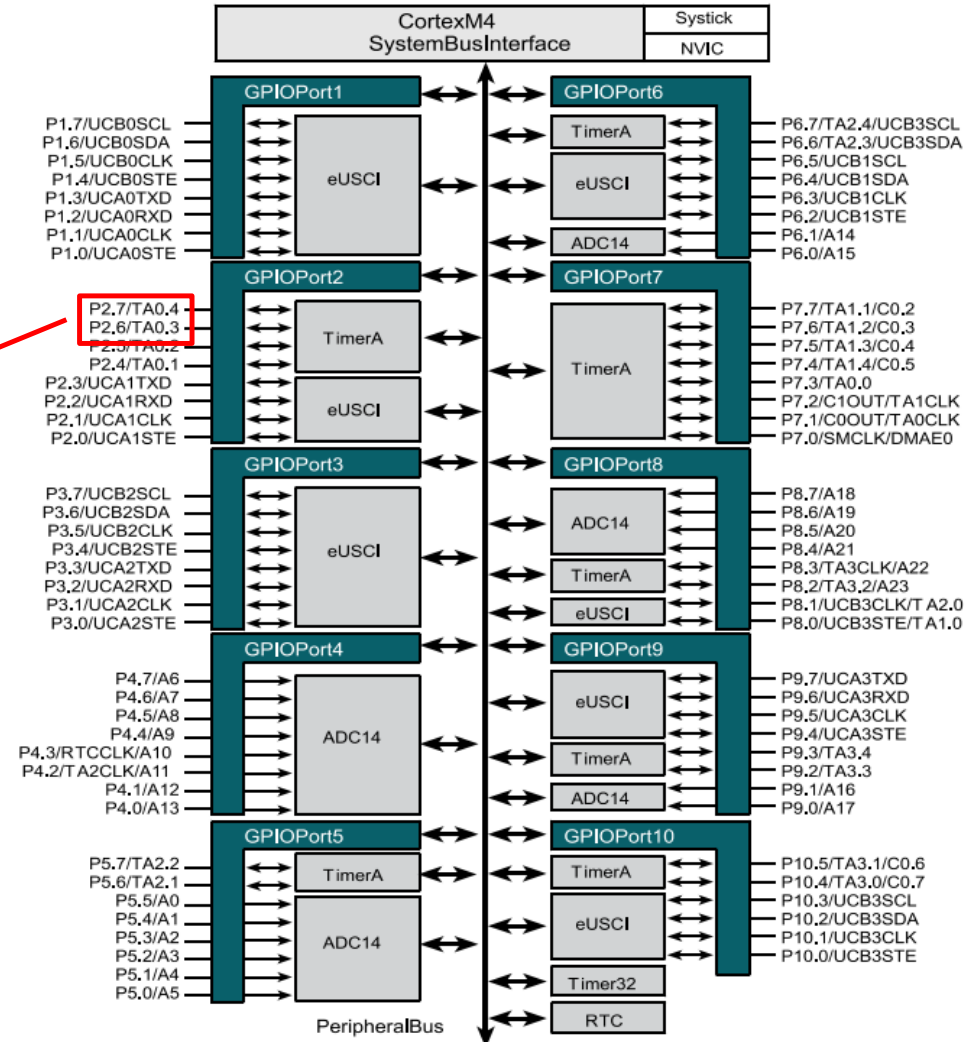
```
void motor_init(void) {  
    P3->SEL0 &= ~0xC0;  
    P3->SEL1 &= ~0xC0;          // 1) configure nSLPR & nSLPL as GPIO  
    P3->DIR |= 0xC0;             // 2) make nSLPR & nSLPL as output  
    P3->OUT &= ~0xC0;           // 3) output LOW  
  
    P5->SEL0 &= ~0x30;  
    P5->SEL1 &= ~0x30;          // 1) configure DIRR & DIRL as GPIO  
    P5->DIR |= 0x30;            // 2) make DIRR & DIRL as output  
    P5->OUT &= ~0x30;           // 3) output LOW  
  
    P2->SEL0 &= ~0xC0;  
    P2->SEL1 &= ~0xC0;          // 1) configure PWMR & PWML as GPIO  
    P2->DIR |= 0xC0;            // 2) make PWMR & PWML as output  
    P2->OUT &= ~0xC0;           // 3) output LOW  
  
    pwm_init34(7500, 0, 0);  
}
```

```
void pwm_init34(uint16_t period, uint16_t duty3, uint16_t duty4) {  
    // CCR0 period  
    TIMER_A0->CCR[0] = period;  
  
    // divide by 1  
    TIMER_A0->EX0 = 0x0000;  
  
    // toggle/reset  
    TIMER_A0->CCTL[3] = 0x0040;  
    TIMER_A0->CCR[3] = duty3;  
    TIMER_A0->CCTL[4] = 0x0040;  
    TIMER_A0->CCR[4] = duty4;  
  
    // 0x200 -> SMCLK  
    // 0b1100 0000 -> input divider /8  
    // 0b0011 0000 -> up/down mode  
    TIMER_A0->CTL = 0x02F0;  
  
    // set alternative  
    P2->DIR |= 0xC0;  
    P2->SEL0 |= 0xC0;  
    P2->SEL1 &= ~0xC0;  
}
```

# MSP432 Port Map

GPIO → 직접 PWM 신호 ...

Motor's PWM pins are connected to  
timer0's 3&4 submodules



## DC Motor Interfaces

```
void move(uint16_t leftDuty, uint16_t rightDuty) {
    P3->OUT |= 0xC0;
    TIMER_A0->CCR[3] = leftDuty;
    TIMER_A0->CCR[4] = rightDuty;
}

void left_forward() {
    P5->OUT &= ~0x10;
}

void left_backward() {
    P5->OUT |= 0x10;
}

void right_forward() {
    P5->OUT &= ~0x20;
}

void right_backward() {
    P5->OUT |= 0x20;
}
```

## Example

```
void main(void)
{
    // Initialization
    Clock_Init48MHz();
    systick_init();
    motor_init();

    while (1) {
        left_forward();
        right_forward();
        move(2000, 2000);
        systick_wait1s();

        left_forward();
        right_forward();
        move(1000, 3000);
        systick_wait1s();
    }
}
```

### **3. Activity**



