TI-RSLK

Texas Instruments Robotics System Learning Kit

Texas Instruments

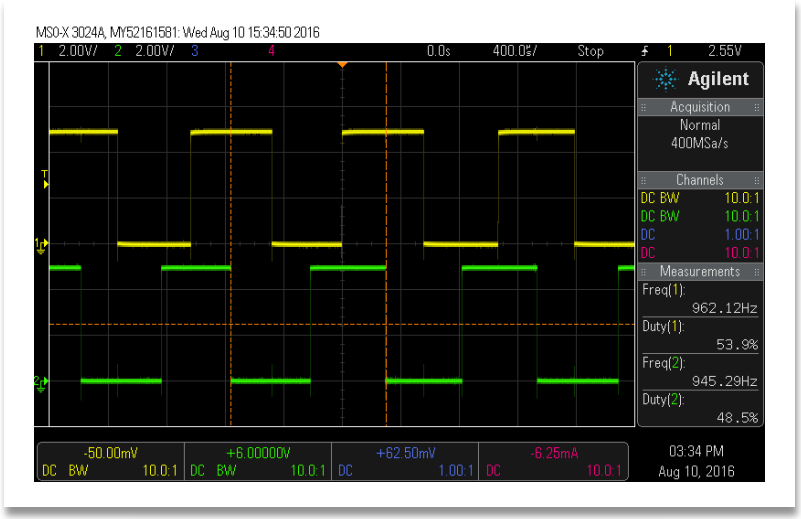
Module 16

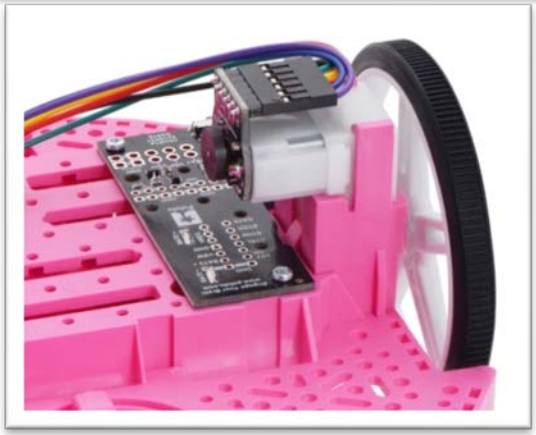
Lecture: Tachometer - Input Capture

Tachometer

You will learn in this module

- Timer A
  - Clock input, prescale
  - Input capture
- Period Measurement
  - Precision
  - Range
  - Resolution
- Motor Performance
  - Speed
  - Time constant

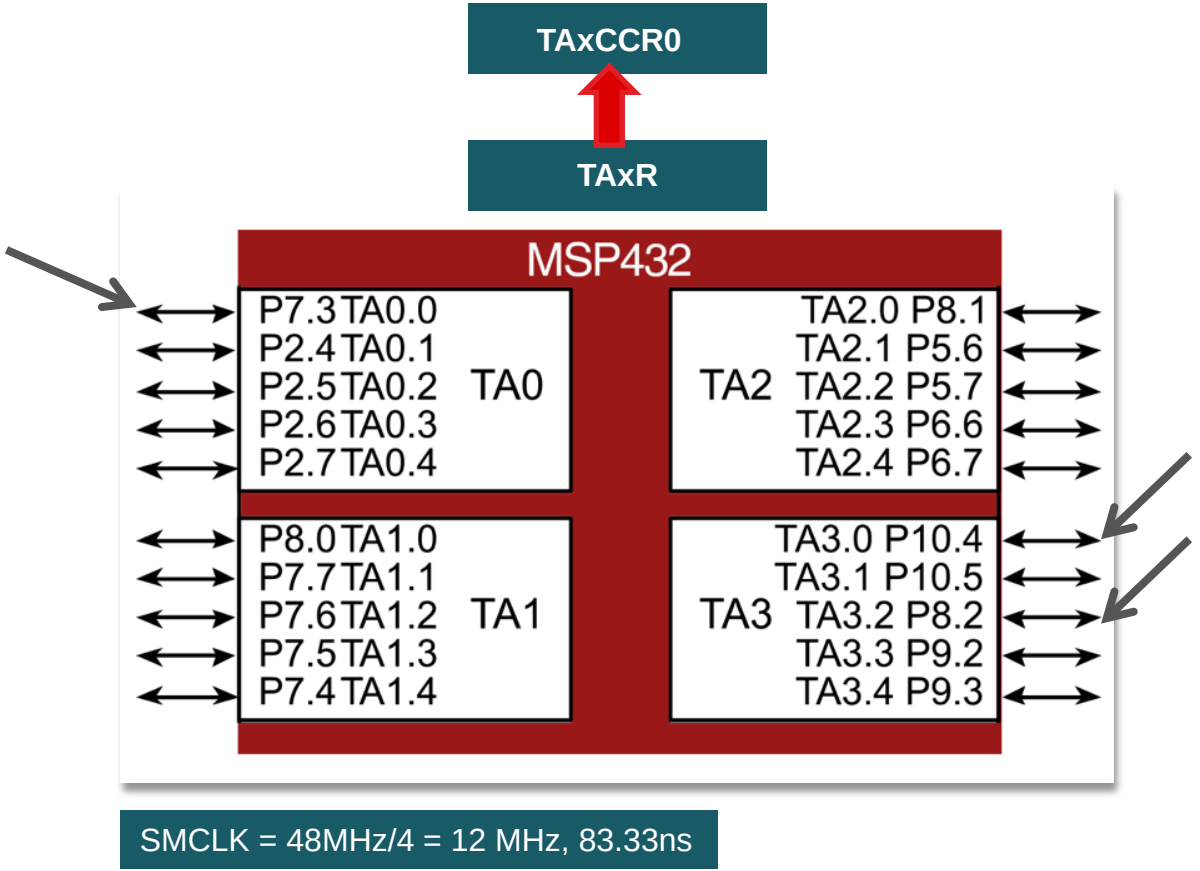




Timer_A for input and output

Components

- Pins
  - Input capture
  - Output compare
- Precision
  - 16-bits
- Resolution
  - Clock period
  - Prescale



SMCLK = 48MHz/4 = 12 MHz, 83.33ns

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 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
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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
	// 01,	00,	1,	0,	0,	1,	000,	1,	0,	0,	0,	0	0CCTL4
													0CCTL5
													0CCTL6

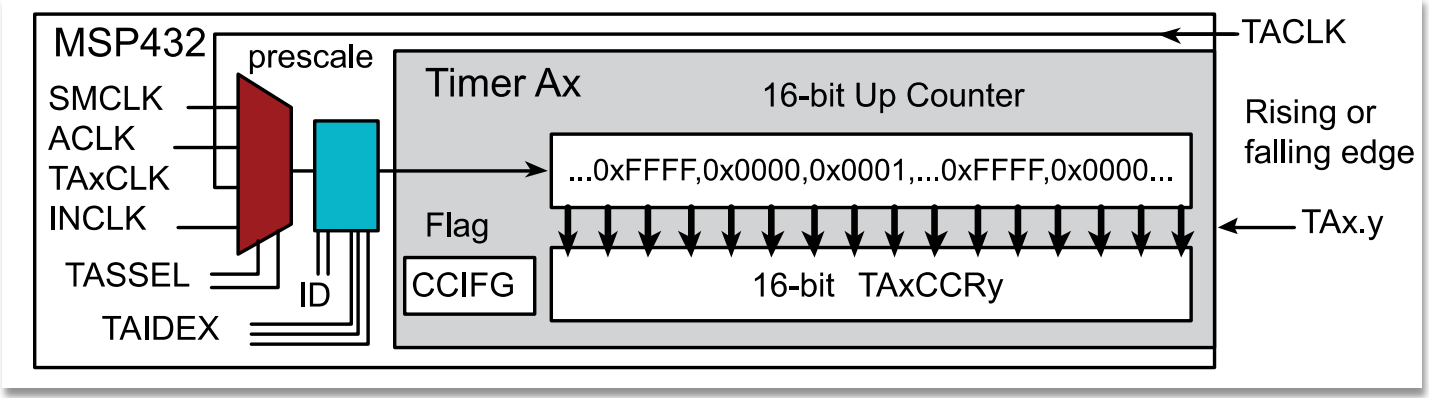
```
TIMER_A0->CCTL[0] = 0x4910;
```

	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

Clock and prescale



TASSEL	Selected Clock
00	TAxCLK
01	ACLK
10	SMCLK
11	INCLK

ID	Prescale
00	/1
01	/2
10	/4
11	/8

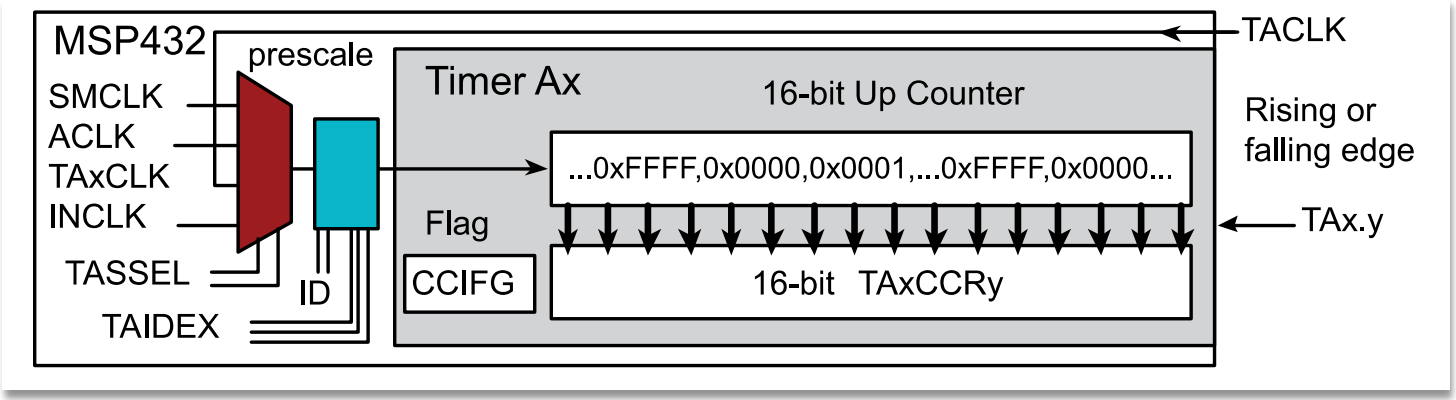
Resolution = $T * 2^{ID} * (\mathbf{TAIDEX}+1)$
Range = Precision * Resolution

Timer_A Modes

CM	Capture mode
00	No capture
01	Capture on rising edge
10	Capture on falling edge
11	Capture on both rising and falling edges

CM	bits15-14=01	capture on rising edge
CCIS	bits13-12=00	capture input on CCIxA
SCS	bit 11=1	synchronous capture source
CAP	bit 8=1	capture mode
CCIE	bit 4=1	arm for interrupt
CCIFG	bit 0=0	trigger, set by hardware, cleared by software

Clock and prescale



0) Halt the timer (MC=00),

1) Set the timer clock and prescale,

2) Set submodule 0 to capture rising, arm interrupt

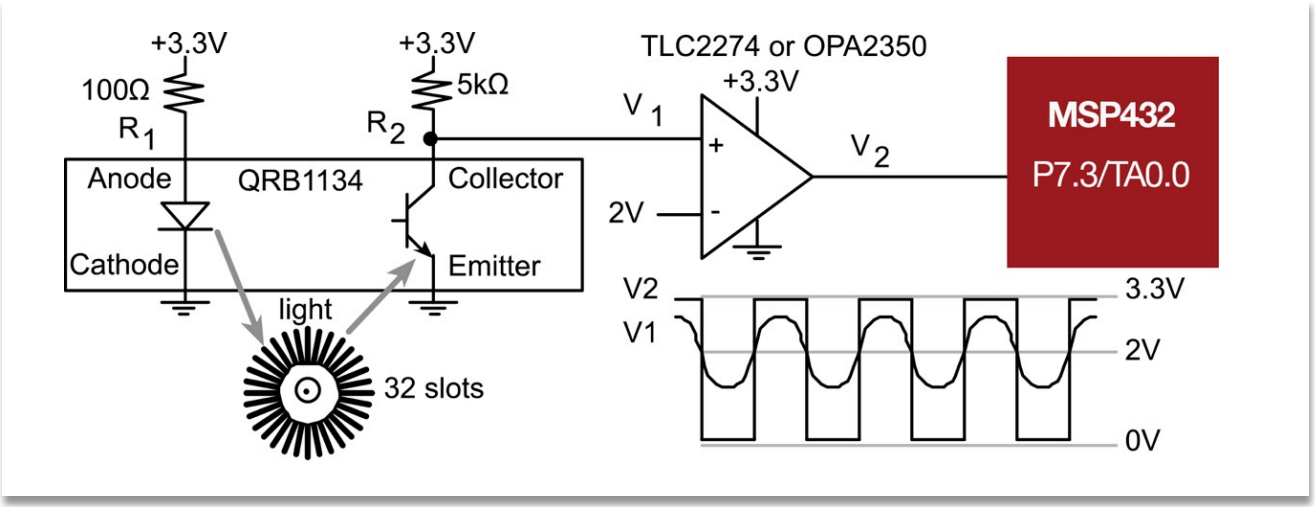
3) Set the priority in the correct NVIC Priority register

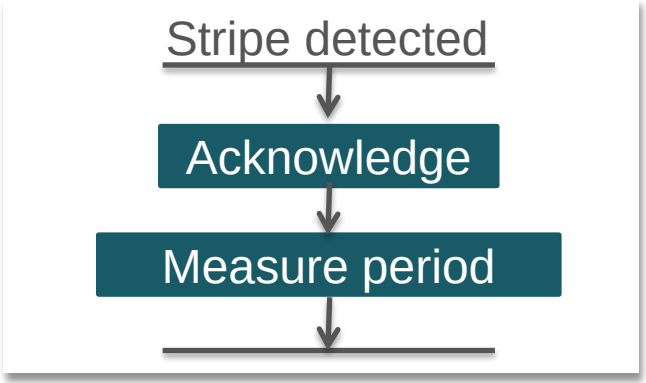
4) Enable the interrupt in the NVIC Interrupt Enable register

5) Reset the timer and start it in up mode

6) Enable interrupts (in the main program after all devices initialized)

Period Measurement Example





Period Measurement Example

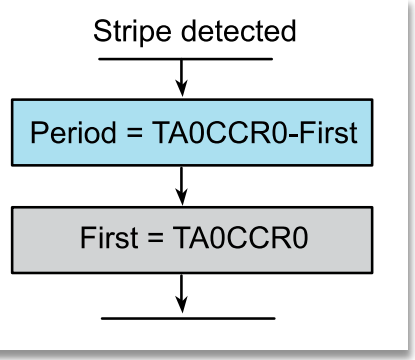
```
void TimerA0Capture_Init(void){
  P7->SEL0 |= 0x08;
  P7->SEL1 &= ~0x08;    // configure P7.3 as TA0CCP0
  P7->DIR &= ~0x08;       // make P7.3 in
  TIMER_A0->CTL &= ~0x0030;      // halt Timer A0
  // bits9-8=10,       clock source to SMCLK
  // bits7-6=00,       input clock divider /1
  // bits5-4=00,       stop mode
  TIMER_A0->CTL = 0x0200;
  // bits15-14=01,     capture on rising edge
  // bits13-12=00,     capture/compare input on CCI0A
  // bit11=1,          synchronous capture source
  // bit8=1,           capture mode
  // bit4=1,           enable capture/compare interrupt
  // bit0=0,           clear capture/compare interrupt pending
  TIMER_A0->CCTL[0] = 0x4910;
  TIMER_A0->EX0 &= ~0x0007; // configure for input clock divider /1
  NVIC->IP[2] = (NVIC->IP[2]&0xFFFFFF00)|0x00000040; // priority 2
  NVIC->ISER[0] = 0x00000100; // enable interrupt 8 in NVIC
  TIMER_A0->CTL |= 0x0024;   // reset and start Timer A0 in continuous up mode
}
```

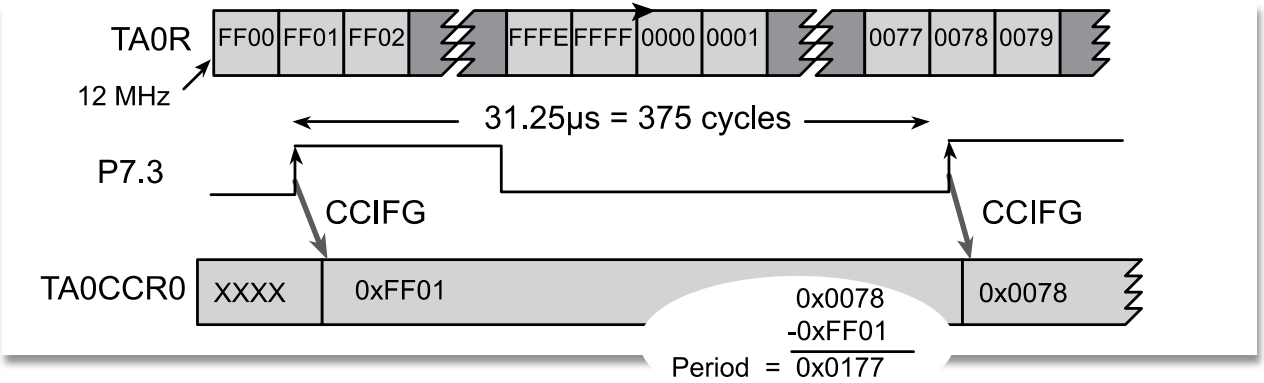
Interrupts enabled in the main program after all devices initialized

Period Measurement

Interrupt on rising edge

```
uint16_t First,Period;
void TA0_0_IRQHandler(void){
  TIMER_A0->CCTL[0] &= ~0x0001;
  // acknowledge capture/compare interrupt 0
  Period = TIMER_A0->CCR[0]-First;
  First = TIMER_A0->CCR[0];
}
```



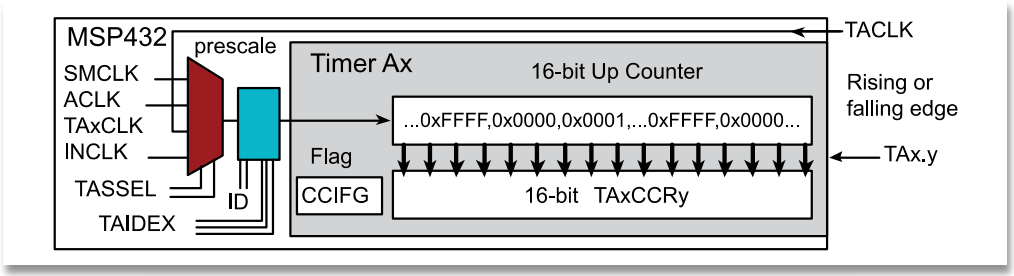


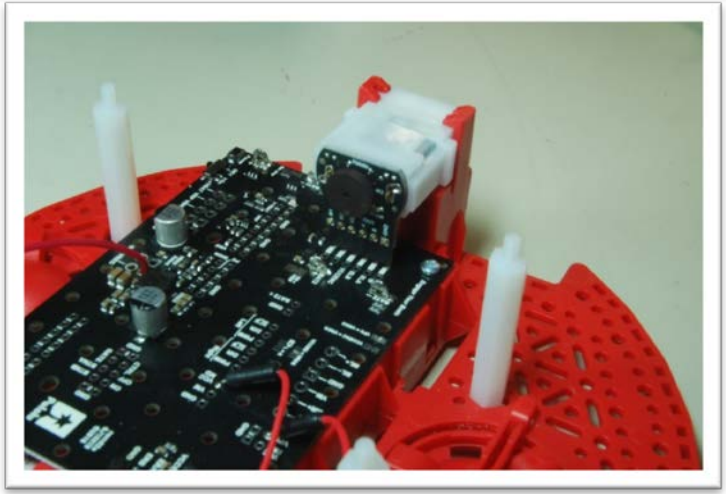
Precision	16 bits
Resolution	83.33ns
Range	10us to 5.4ms

Summary

Measuring speed with input capture

- Timer_A
  - Clock input,
  - Prescale
  - Input capture
- Period Measurement
  - Precision
  - Range
  - Resolution
- Motor Performance
  - Speed
  - Time constant





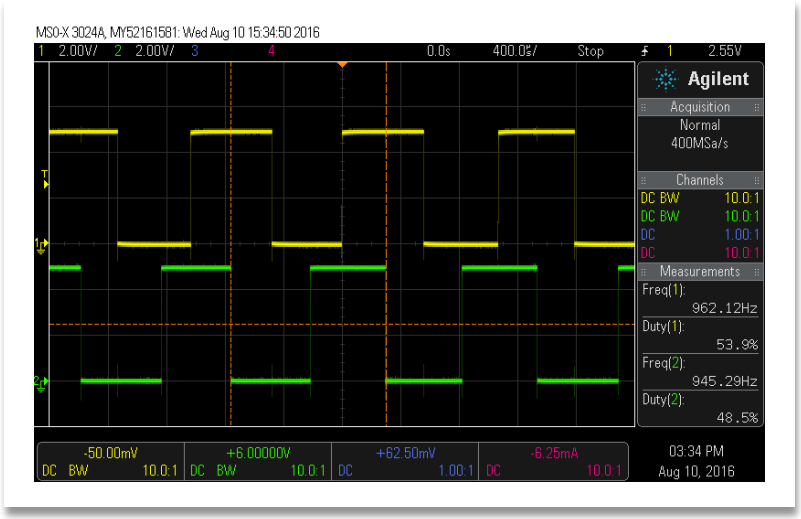
Module 16

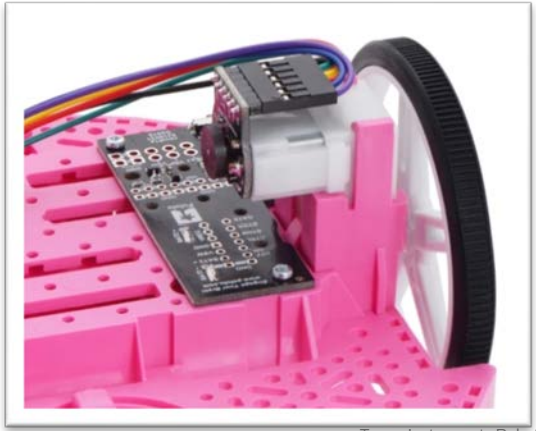
Lecture: Tachometer - Interface

Tachometer

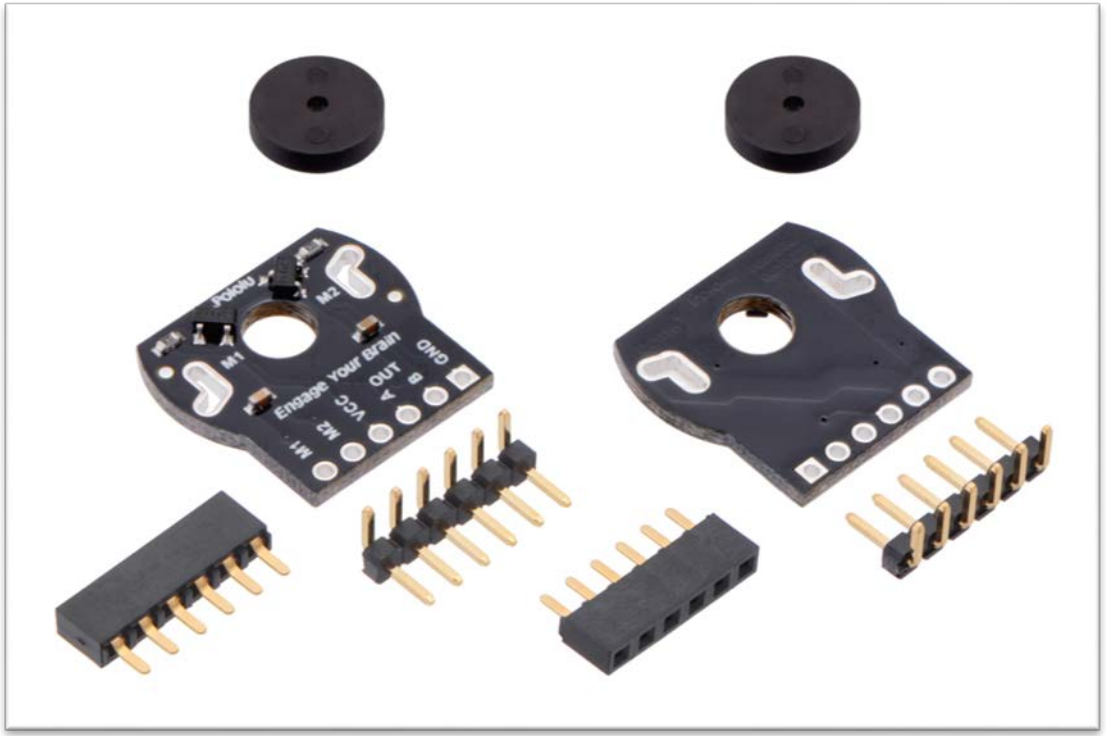
You will learn in this module

- Encoder
  - Motor speed
  - Motor direction
- Motor Performance
  - Speed
  - Time constant





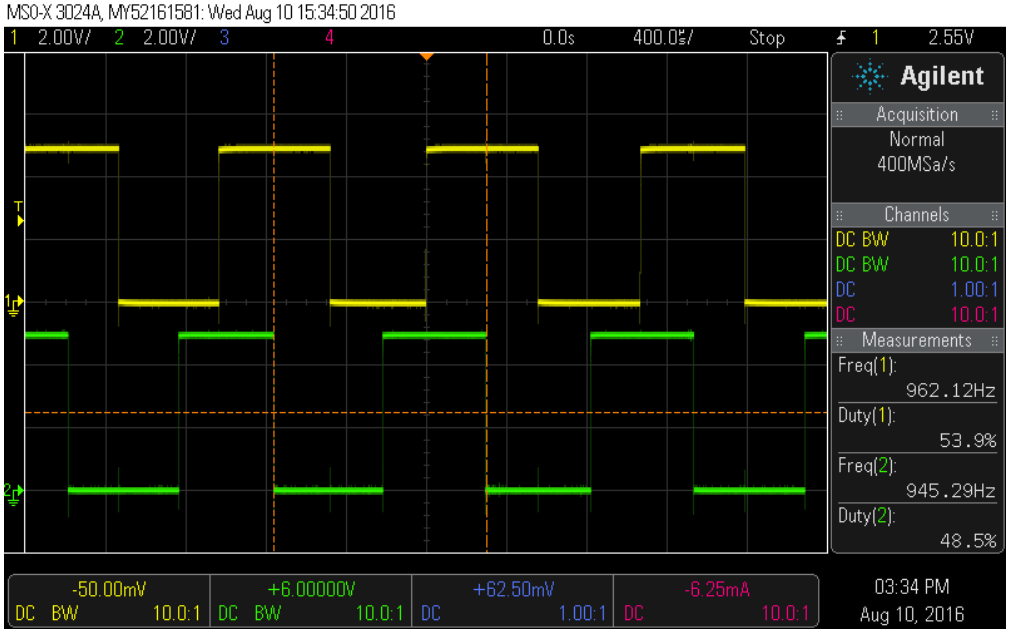
Encoders



360 pulses/rotation

Speed (rpm) =
(1 rotation/360pulses)
*(1,000,000,000ns/sec)
*(60sec/min)
/(Period*83.33ns/pulse)

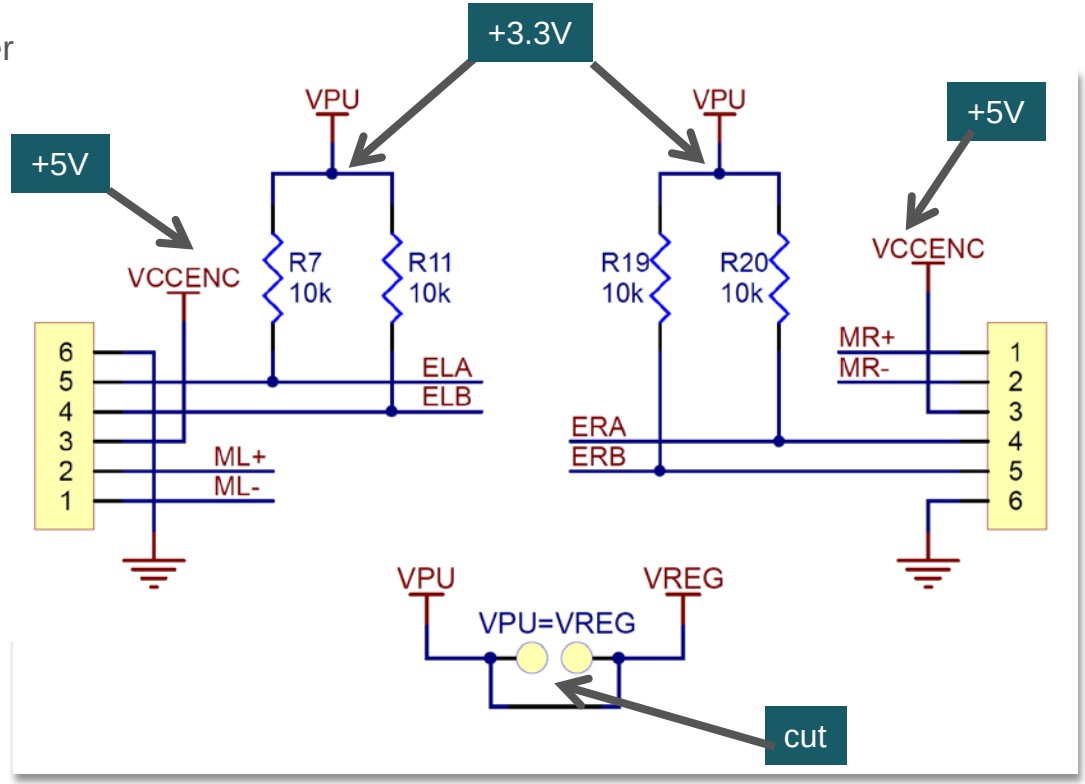
Speed = 2,000,000/Period



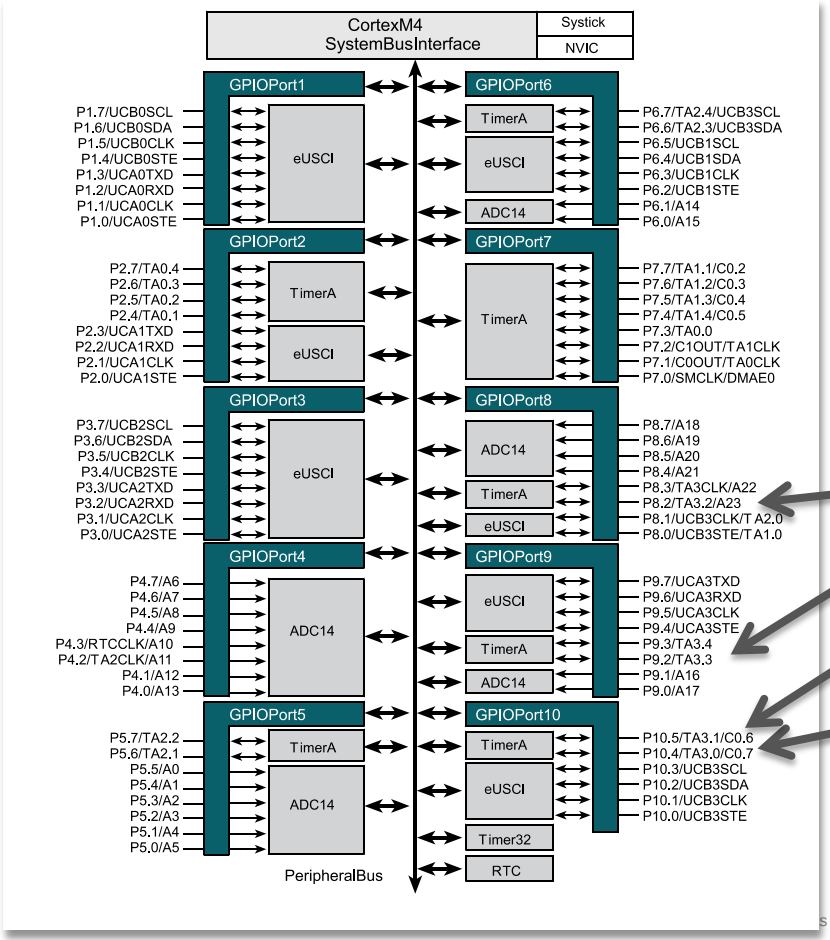
Pololu Board interface of two encoders

Lab 5:

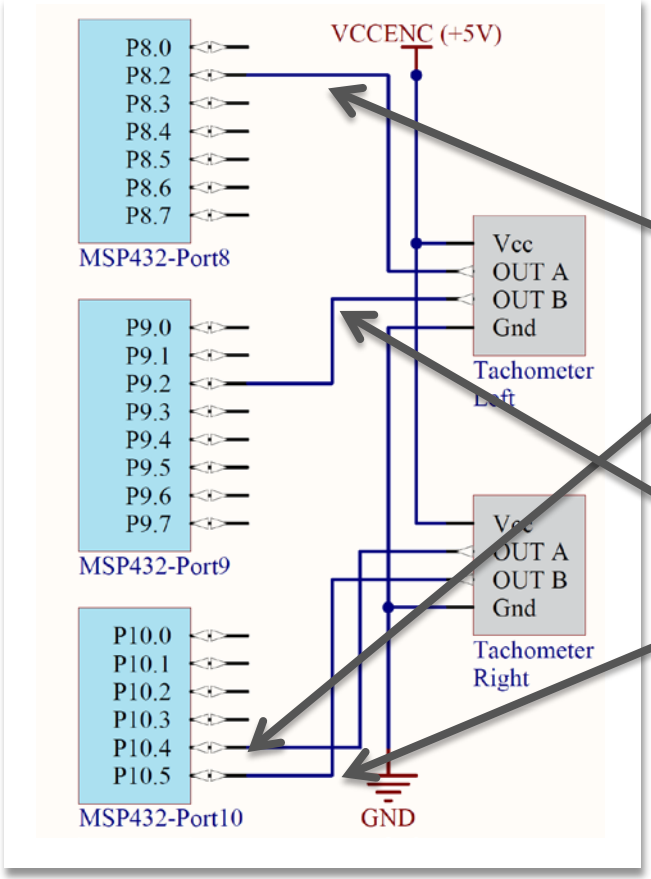
- Cut the VPU—VREG jumper
- Connect VPU to 3.3V



MSP432 Planning



Pololu Board interface of two encoders



Input capture
on P8.2, P10.4

Direction on P9.2, P10.5
- 1 = forward
- 0 = backward

Interrupt Vectors, numbers, names, and priority

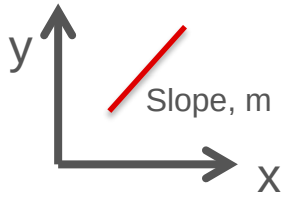
Vector	Number	IRQ	ISR name	NVIC priority	Priority
0x0000002C	11	-5	**SVC_Handler**	**SCB_SHPR2**	31 – 29
0x00000038	14	-2	**PendSV_Handler**	**SCB_SHPR3**	23 – 21
0x0000003C	15	-1	**SysTick_Handler**	**SCB_SHPR3**	31 – 29
0x00000060	24	8	**TA0_0_IRQHandler**	**NVIC_IPR2**	7 – 5
0x00000064	25	9	**TA0_N_IRQHandler**	**NVIC_IPR2**	15 – 13
0x00000068	26	10	**TA1_0_IRQHandler**	**NVIC_IPR2**	23 – 21
0x0000006C	27	11	**TA1_N_IRQHandler**	**NVIC_IPR2**	31 – 29
0x00000070	28	12	**TA2_0_IRQHandler**	**NVIC_IPR3**	7 – 5
0x00000074	29	13	**TA2_N_IRQHandler**	**NVIC_IPR3**	15 – 13
0x00000078	30	14	**TA3_0_IRQHandler**	**NVIC_IPR3**	23 – 21
0x0000007C	31	15	**TA3_N_IRQHandler**	**NVIC_IPR3**	31 – 29
0x00000080	32	16	**EUSCIA0_IRQHandler**	**NVIC_IPR4**	7 – 5
0x00000084	33	17	**EUSCIA1_IRQHandler**	**NVIC_IPR4**	15 – 13
0x00000088	34	18	**EUSCIA2_IRQHandler**	**NVIC_IPR4**	23 – 21
0x0000008C	35	19	**EUSCIA3_IRQHandler**	**NVIC_IPR4**	31 – 29
0x00000090	36	20	**EUSCIB0_IRQHandler**	**NVIC_IPR5**	7 – 5
0x				**R5**	15 – 13
0x				**R5**	23 – 21
0x				**R5**	31 – 29
0x				**R8**	31 – 29
0x				**R9**	7 – 5
0x				**R9**	15 – 13
0x				**R9**	23 – 21
0x				**R9**	31 – 29
0x				**R10**	7 – 5

```
void TA3_0_IRQHandler(void){
  TIMER_A3->CCTL[0] &= ~0x0001; // ack
// body
}
void TA3_N_IRQHandler(void){
  TIMER_A3->CCTL[2] &= ~0x0001; // ack
// body
}
```

Motor Model

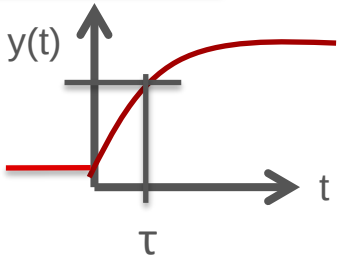
Duty cycle, X(t) → Motor → Speed Y(t)

Linear model
- Gain, m
- Time constant, τ



Duty cycle, X(s) → Motor → Speed Y(s)

$$H(s) = \frac{Y(s)}{X(s)} = \frac{m}{1+s\tau}$$

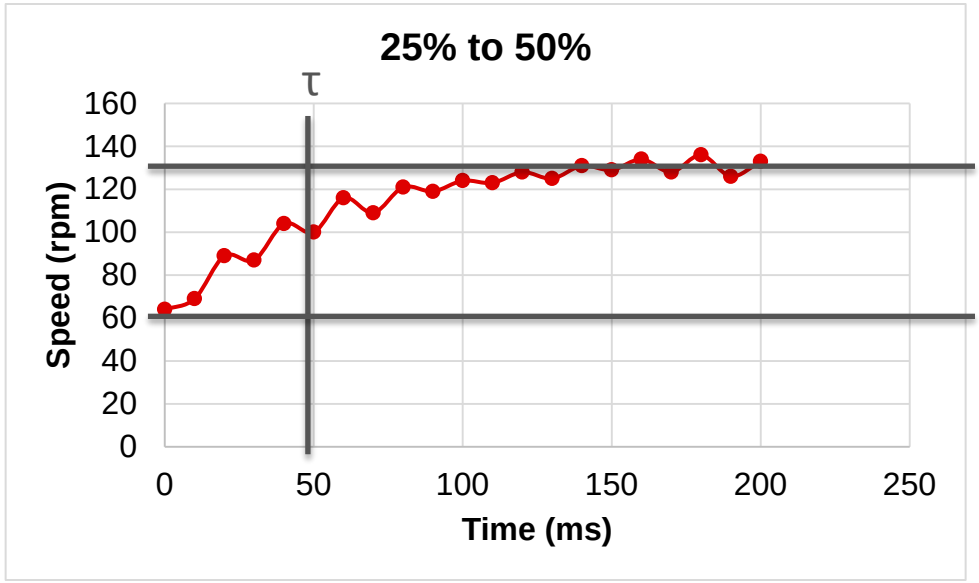


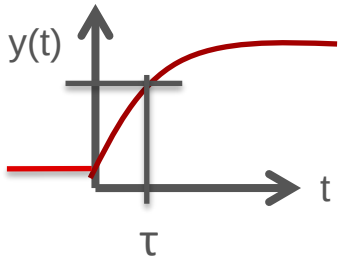
Motors are not linear
Friction affects everything

$$y(t) = S_0 + \Delta S\, e^{-t/\tau}$$

Motor Time Constant

Duty cycle, X(t) → Motor → Speed Y(t)





$$y(t) = S_0 + \Delta S\, e^{-t/\tau}$$

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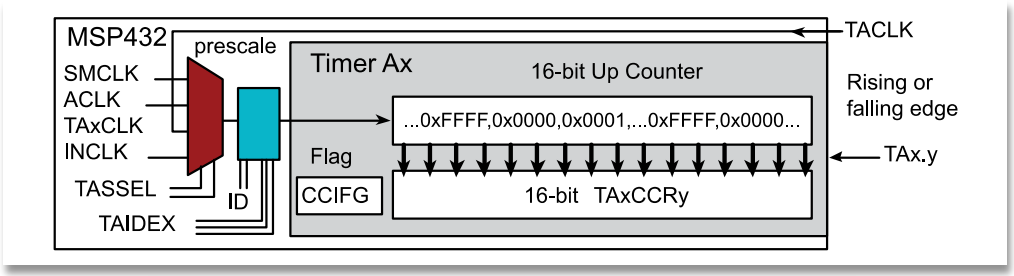

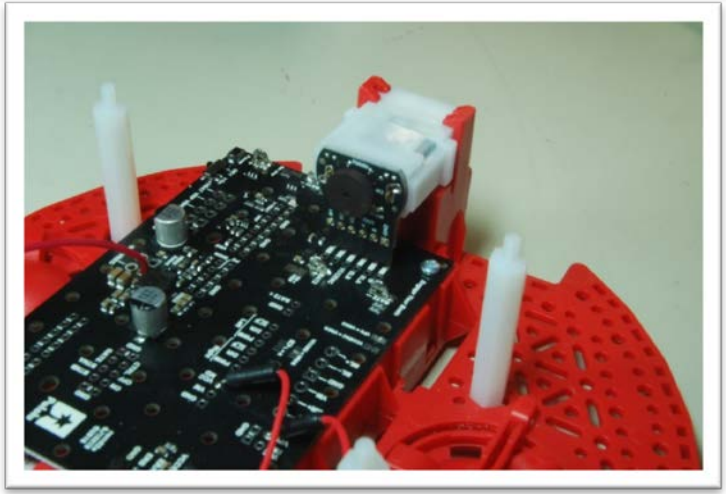

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