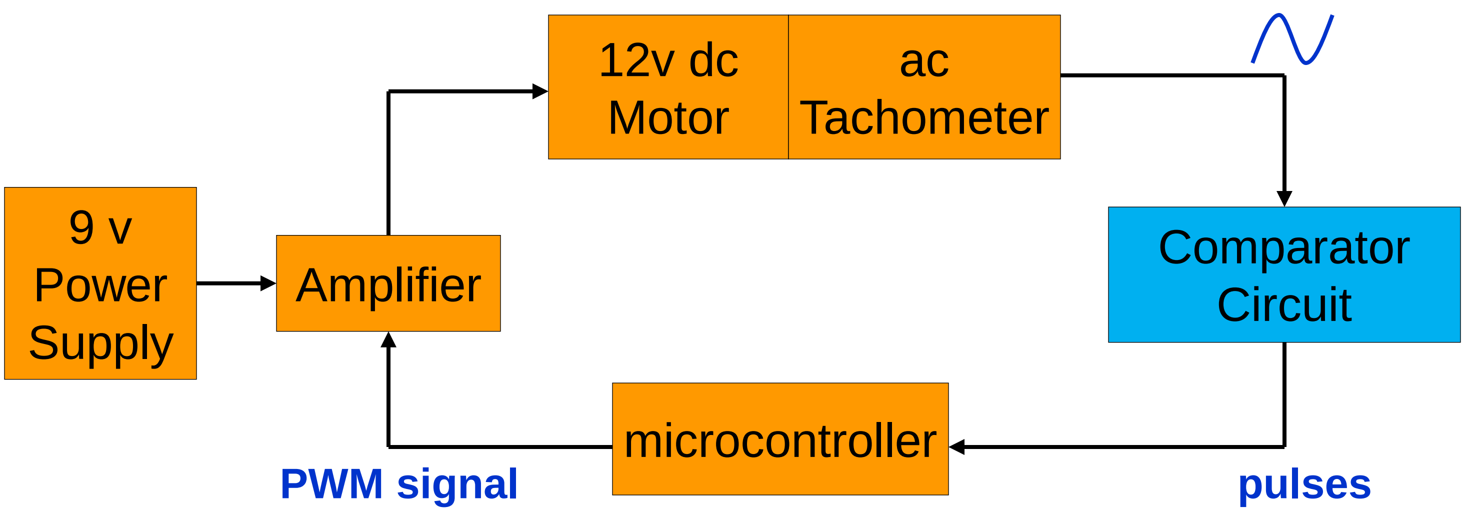
Lab 9. Speed Control of a D.C. motor

Sensing Motor Speed

(Tach Frequency Method)

Motor Speed Control Project

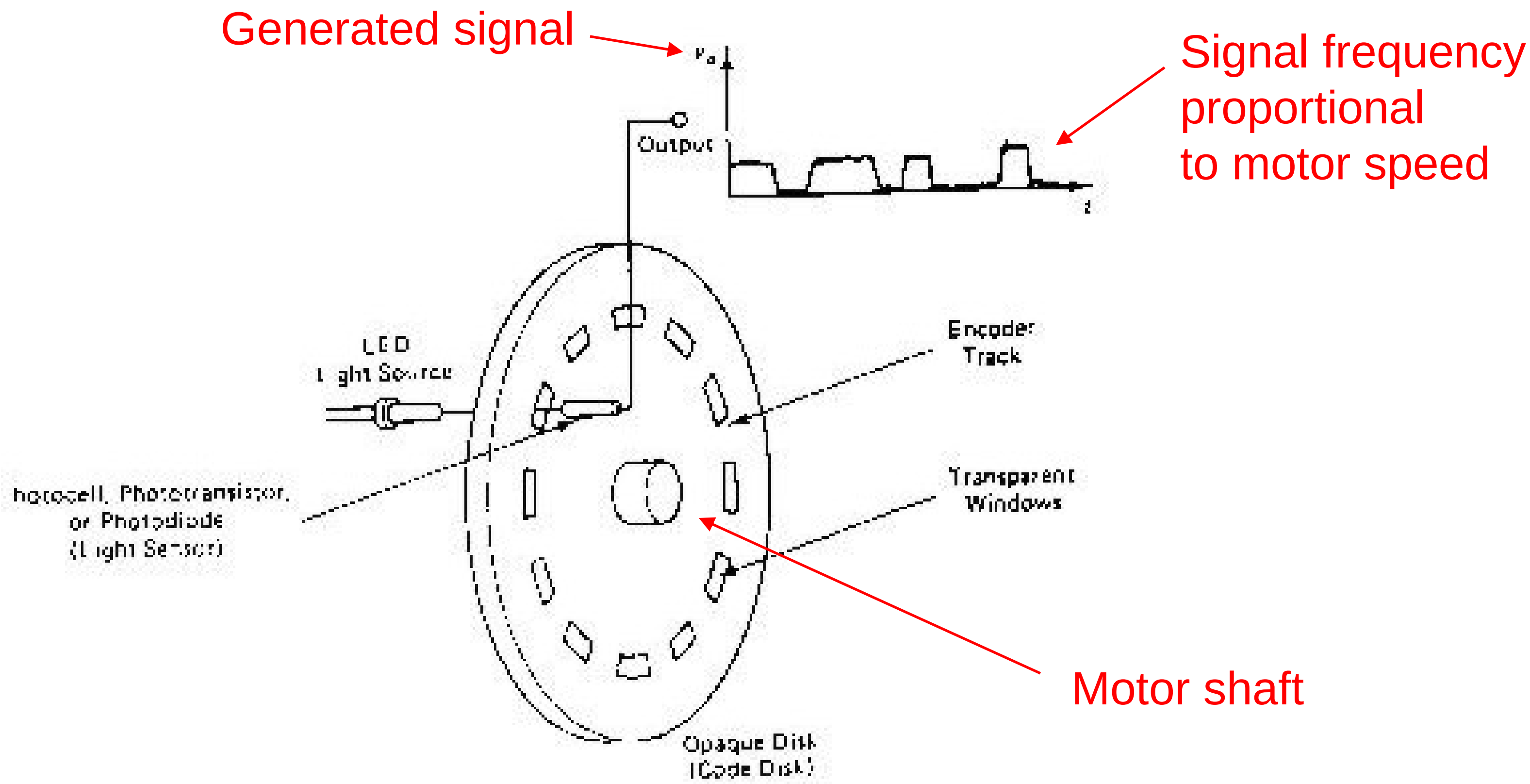
1. Generate PWM waveform
2. Amplify the waveform to drive the motor
3. Measure motor speed
4. Measure motor parameters
5. Control speed with a computer algorithm



Tachometer circuits

- Electrical signal carries speed information (revolutions per unit time) in amplitude and/or frequency
  - Optical encoder: disk on motor shaft alternately blocks and passes light to a sensor
  - Variable reluctance tachometer: gear teeth pass a magnetic pickup
  - Pickup coil: voltage induced on separate winding in the motor

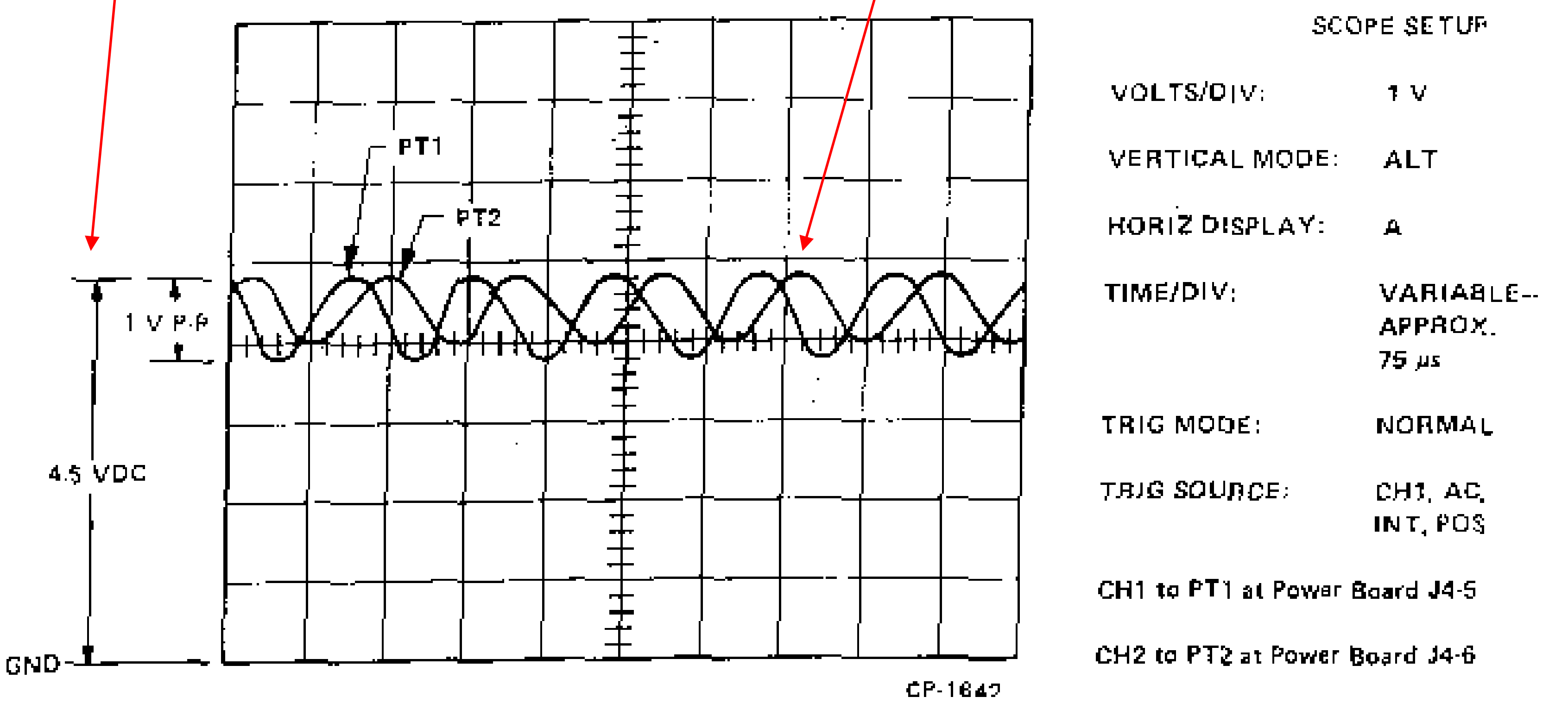
Optical Encoder



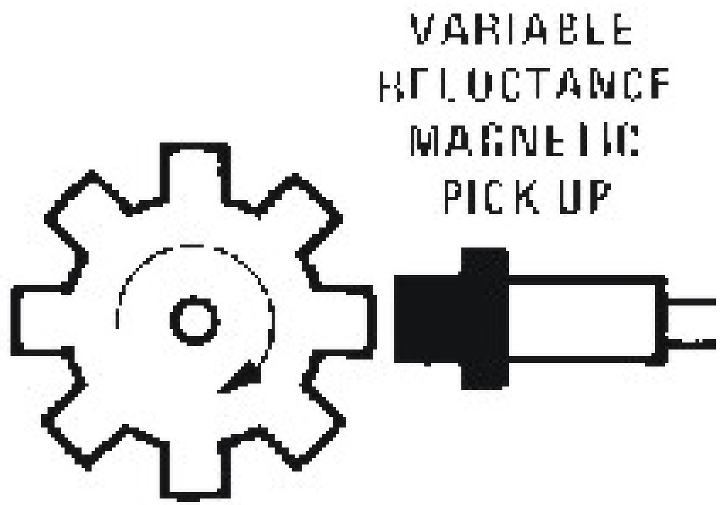
PT1 and PT2 waveforms
(two sensors indicate speed and direction)

Note D.C. component

About 1 volt peak-to-peak variation

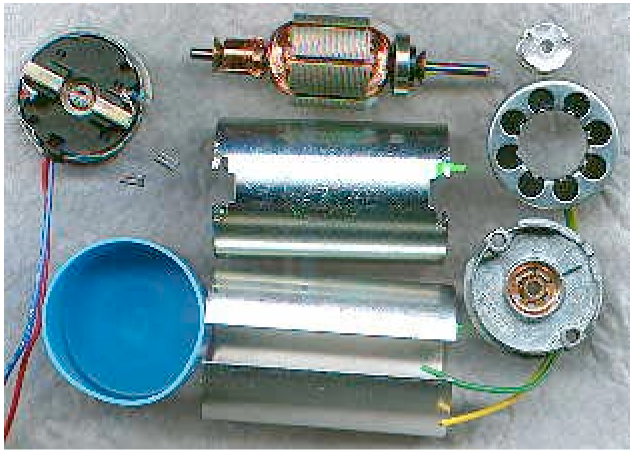


Variable reluctance magnetic pickup



Generated signal similar to optical encoder

Pickup coil (Buehler motor)



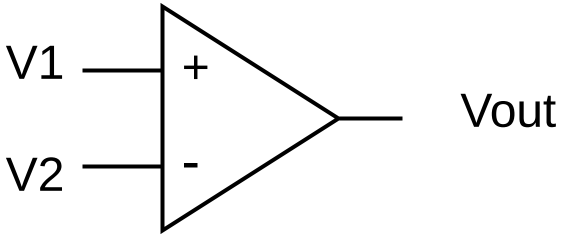
- Voltage induced in separate coil at one end of rotor
- Both frequency and amplitude of the generated signal are proportional to motor speed
  - DC offset = 0v

Signal frequency measurement

1. Convert frequency to an analog voltage, and then to digital form
   - use commercial F-to-V integrated circuit
   - digitize voltage level with A/D converter
2. Count # signal periods per unit of time
   - frequency = # periods / time
   - count periods with programmable timer/counter
3. Measure one signal period (T)
   - frequency = 1 / T
   - measure period with programmable timer

Methods 2 & 3: signal conditioning

- Convert tachometer output to digital form
  - Tach signal form: sinusoid with 0 V dc offset
    - Amplitude ranges from 0V to over 12 V peak
  - Desired form: square wave, oscillating between 0 and 5 V
- Convert using an analog “comparator”



  - Vout = 0 V for V1 < V2 (logic 0)
  - Vout = 5 V for V1 > V2 (logic 1)

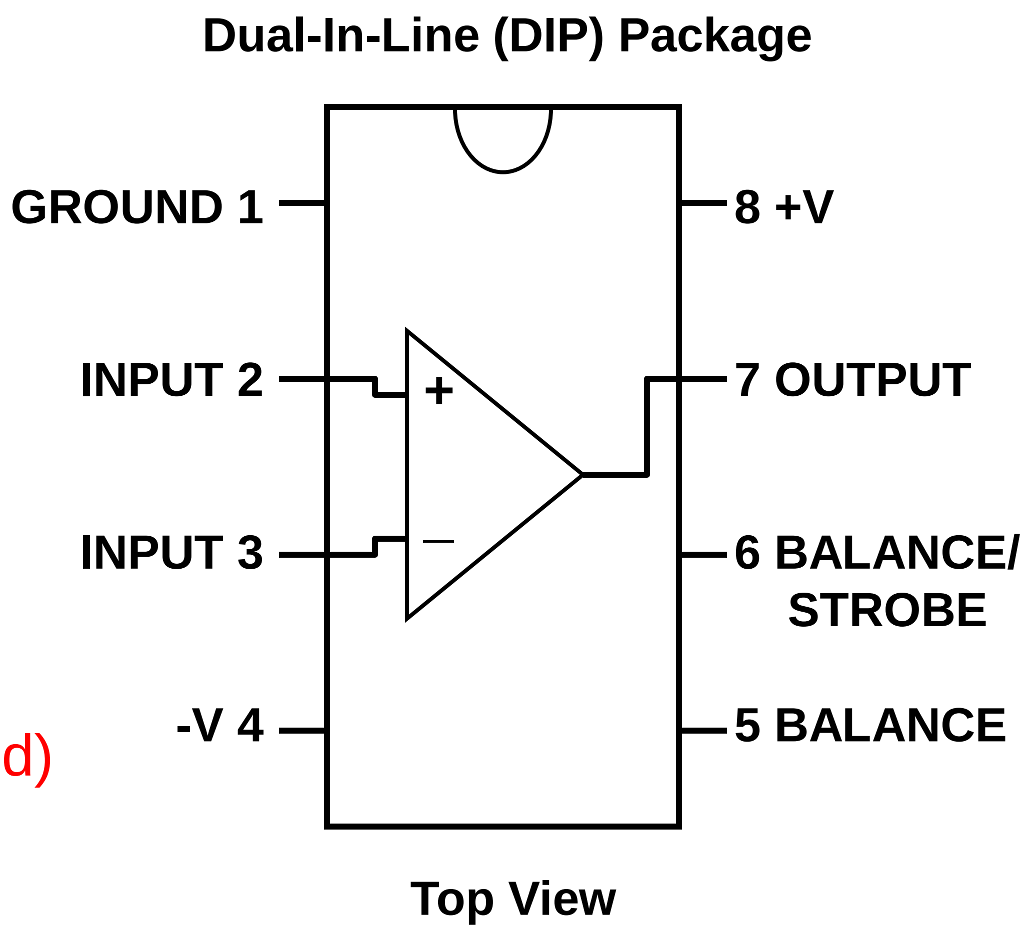
LM111/LM211/LM311 voltage comparators

- Nearly identical, except for temperature range
  - LM111 [-55^{o}C…+125^{o}C] (military)
  - LM211 [-25^{o}C…+85^{o}C] (industrial)
  - LM311 [0^{o}C…+70^{o}C] (commercial)
- Power supplies from ±5 V to ±15 V
- Input voltage range ±30 V
- Output can drive loads to ground, to positive supply, or to negative supply
- Output balancing and strobe capability

LM111 / LM211 / LM311 Package

Pin # Function (lab value)

1. Ground (0 V)
2. V1 input
3. V2 input
4. -V supply (-9 V)
5. Balance*
6. Balance/strobe*
   (*short pins 5-6)
7. Vout (open collector)
   (pullup resistor needed)
8. +V supply (9 V)



Signal & reference voltages

- Goal: V1 > V2 approximately half of each period to get square wave at Vout
- Option 1
  - V1 = ac signal
  - V2 = dc offset of the ac signal
    - remove sinusoid from signal with low pass filter
    - OR, apply a constant voltage ≈ dc offset
- Option 2
  - V1 = ac signal with dc offset removed by high pass filter
  - V2 = ground (0v)

Buehler motor tachometer signal offset is approximately 0v

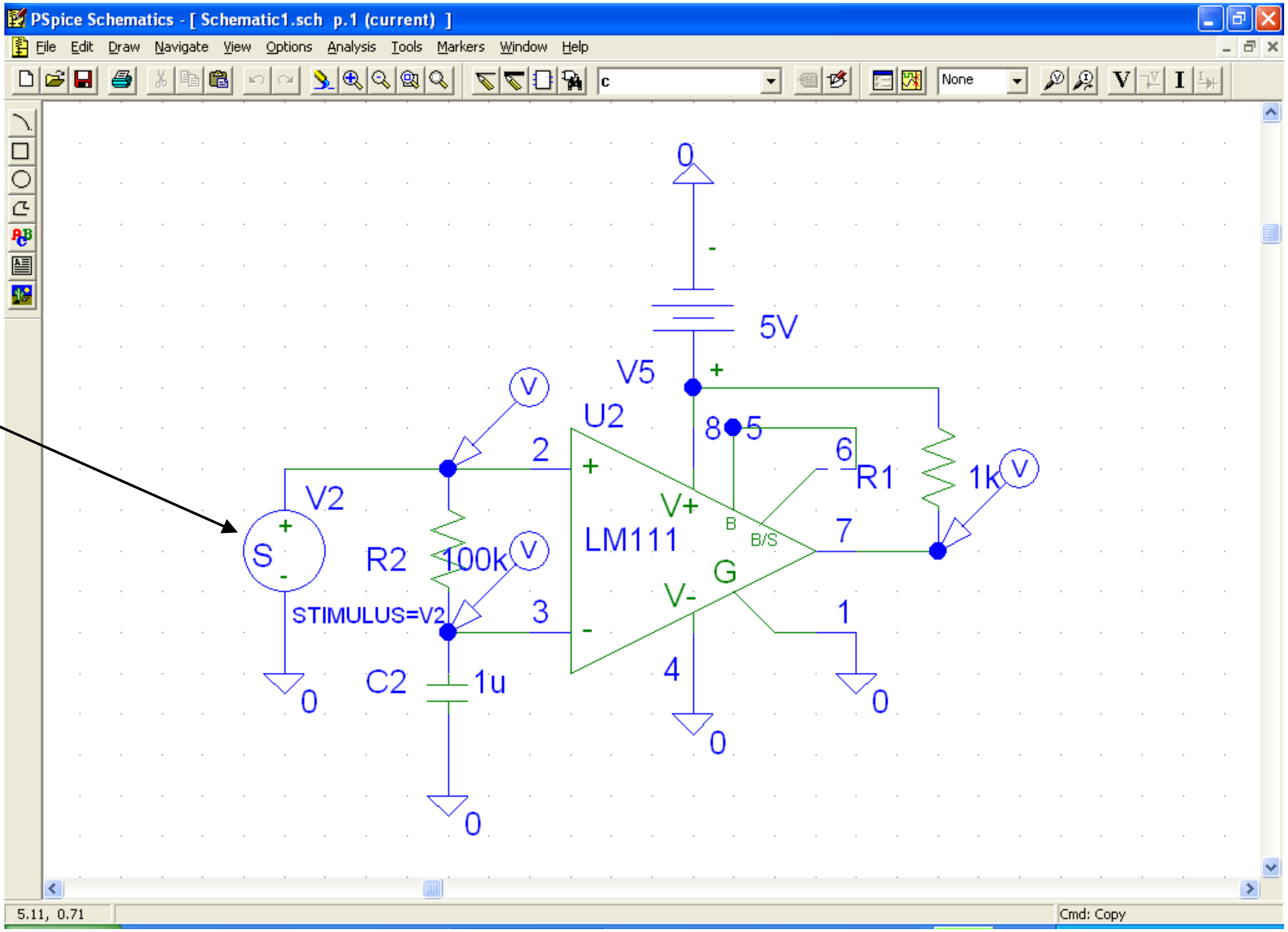
Design & verify comparator circuit

- Model in PSPICE
- LM311 comparator, resistors, DC voltages, etc. found in libraries
- Use a VSTIM (voltage stimulus) generator to model the optical encoder
- Simulate to verify square wave output over the range of optical encoder signal frequencies corresponding to “useful” motor speeds
  - Use voltage probes to examine signals
- Implement circuit and compare actual operation to simulation of the modeled circuit

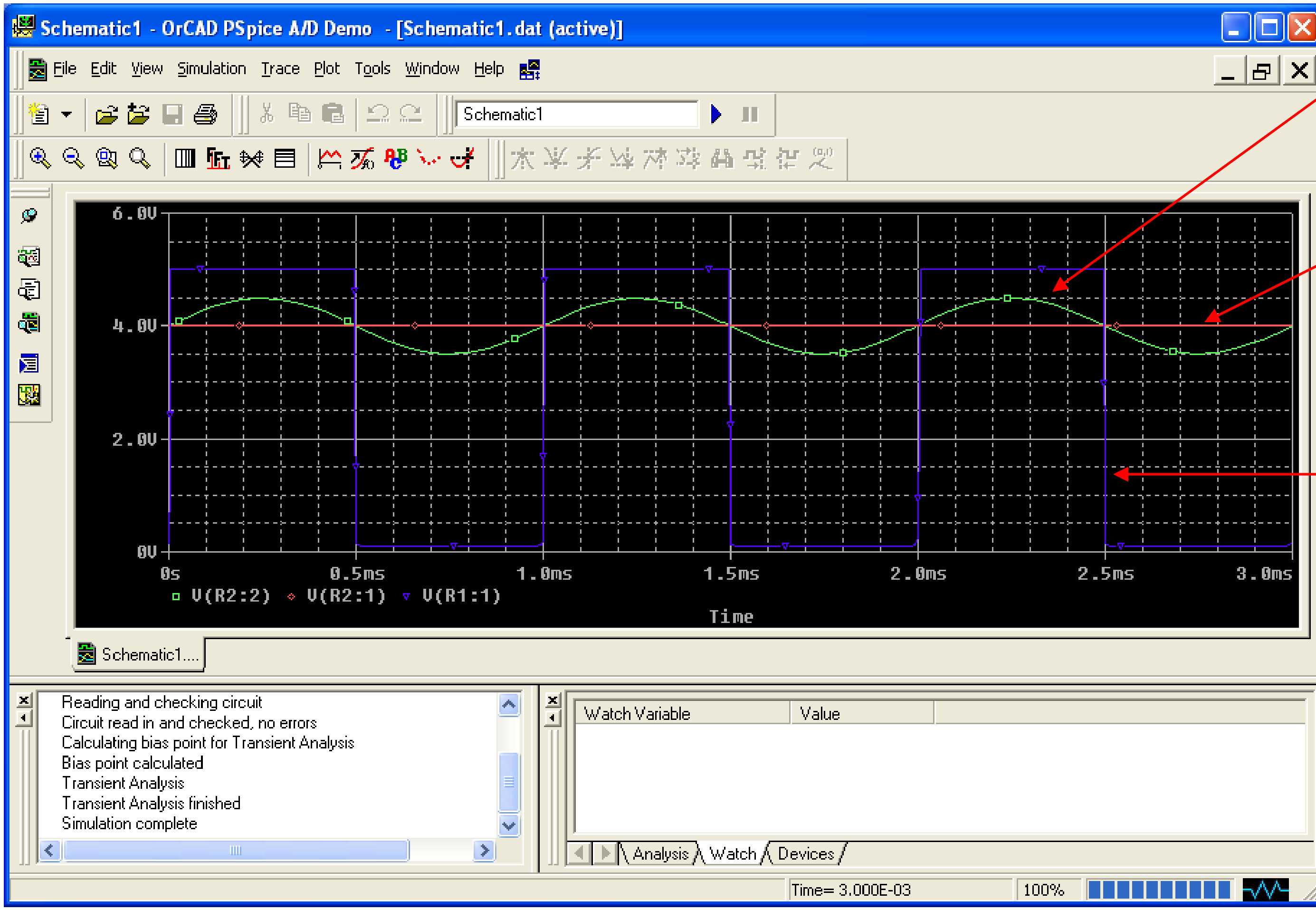
Example model

VSTIM from library "sourcstim"

R,C from "analog" lib. LM111 from "eval" lib. VDC from "source" lib. AGND from "port" lib.



Simulation



ac signal (green)

Low-pass filter output (red)

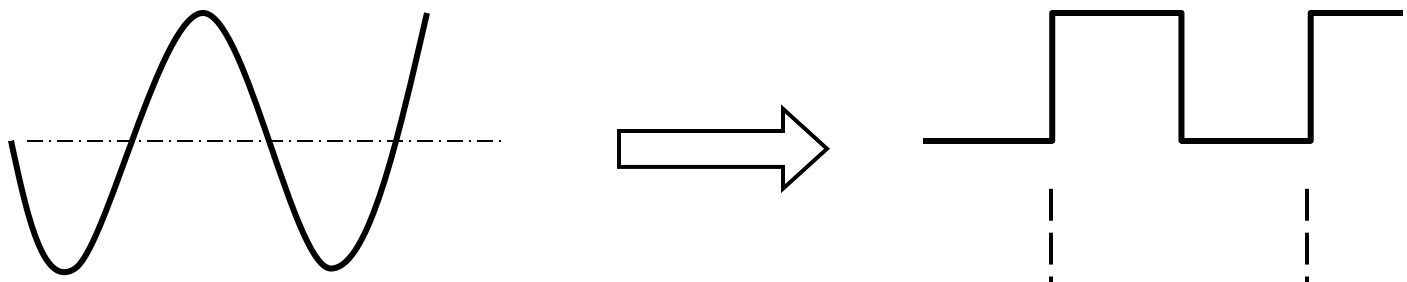
Comparator output (blue)

Circuit design challenges

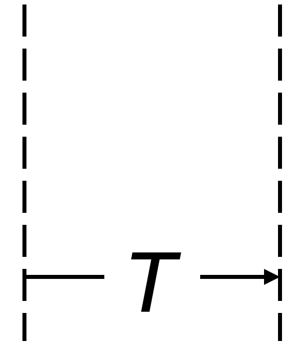
- ac signal will exceed comparator voltage ratings
  - introduce voltage divider?
- ac signal may be noisy
  - may cause "false" transitions
  - introduce hysteresis?

Review

- Convert ac signal to digital signal



- Measure period with timer



HCS12 Timer “Input Capture”

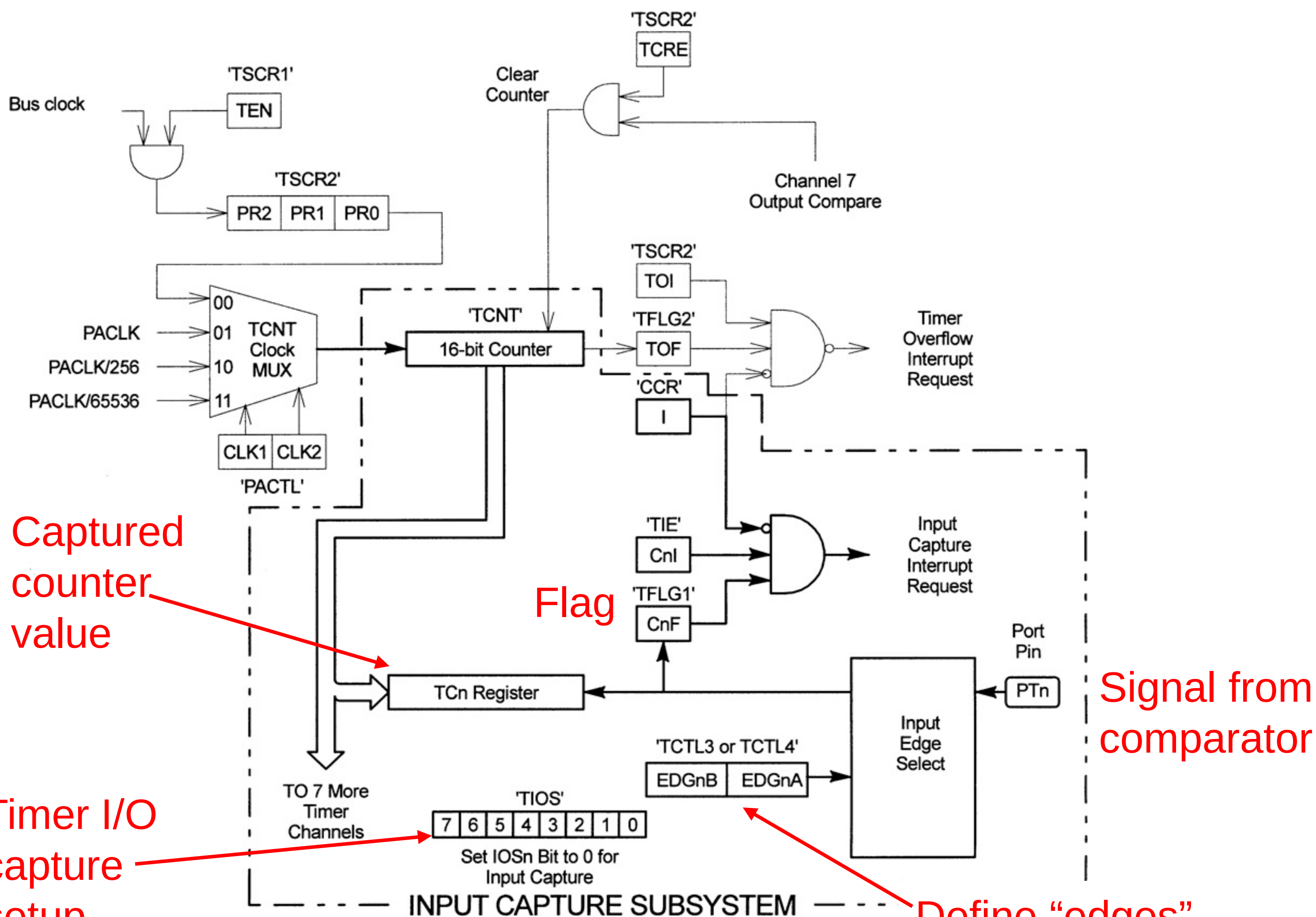


Figure 14-5 Input capture hardware.

Timer Input Capture/Output Compare Select Register (TIOS)

TIOS address: $0080

7	6	5	4	3	2	1	0
IOS7	IOS6	IOS5	IOS4	IOS3	IOS2	IOS1	IOS0

IOSn: Select input capture or output compare mode for channel *n*

- 0 : channel *n* acts as <u>input</u> capture, or GPIO for pin PTn (DDRT sets direction)
- 1 : channel *n* acts as <u>output</u> compare

Timer Control Registers 3 & 4 (TCTL3 or TCTL4)

Define events to be captured on port T pins

	7	6	5	4	3	2	1	0
TCTL3 $004A	EDG7B	EDG7A	EDG6B	EDG6A	EDG5B	EDG5A	EDG4B	EDG4A
TCTL4 $004B	EDG3B	EDG3A	EDG2B	EDG2A	EDG1B	EDG1A	EDG0B	EDG0A

EDGnB:EDGnA – Events on pin PTn

- 00 : input capture disabled (default)
- 01 : Capture on rising edges only
- 10 : Capture on falling edges only
- 11 : Capture on rising or falling edges

Example – Measure the period of a waveform on pin PT1 (Ex. 14-21 in Cady text)

```
     bset  TSCR,#%10000000        ;TEN=1 to enable timer
     bclr  TIOS,#%00000010        ;IOS1=0 (input capture)
     movb  #%00000100,TCTL4       ;EDG1A/B=01(PT1 rise edge)
     movb  #%00000010,TFLG1       ;reset C1F
S1:  brclr TFLG1,%00000010,S1     ;wait for C1F (rising edge)
     ldd   TC1                    ;time of 1st rising edge
     std   First                  ;save it
     movb  #%00000010,TFLG1       ;reset C1F
S2:  brclr TFLG1,%00000010,S2     ;wait for C1F (rising edge)
     ldd   TC1                    ;time of 2nd rising edge
     subd  First                  ;period=2nd edge time – 1st
     std   Period
```

Example – Measure the period of a waveform on pin PT1 using interrupts

```
    movw  #0,Period             ;initialize measured period
    movw  #1,Count              ;count edges
    bset  TSCR,#%10000000       ;TEN=1 to enable timer
    bclr  TIOS,#%00000010       ;IOS1=0 (input capture)
    movb  #%00000100,TCTL4      ;EDG1A/B=01(PT1 rise edge)
    movb  #%00000010,TFLG1      ;reset C1F
    bset TMSK1,%00000010        ;set C1I to enable ch. 1 interrupt
    cli                         ;enable CPU interrupts
      ...do some other processing
; Timer interrupt routine – entered on PT1 rising edge
isr:  ldd   TC1                       ;time of rising edge
      subd  Period                    ;this edge - previous
      std   Period                    ;save 1st edge time or period
      movb  #%00000010,TFLG1          ;clear CF1
      inc   Count                     ;1 if 1st edge, 2 if period
      rti
      ORG  $FFEC
      dc.w  isr      ;Timer channel 1 interrupt vector
```

Lab Procedure

- Simulate comparator circuit in PSPICE to verify circuit & values
  - Verify that a square wave (0 to 5 V) is produced
- Re-verify motor speed controller from Lab 8

  Note that components can be damaged with incorrect connections/operation! <u>**Triple-check power connections!**</u>
- Incorporate comparator into your circuit
  - Verify comparator inputs & square wave output on o'scope
- Modify software to measure square wave period
- Measure ac tachometer signal period for each of the 10 keypad-selected settings (11th setting is stopped)
- Plot:
  - Signal period vs. measured motor speed
  - Signal period vs. PWM signal duty cycle