EECS192 Lecture 13
Apr. 21, 2020

Notes:
1. Tues 4/28 round 2 in class
2. Oral reports-scheduling TBA
3. Oral final exam- individual schedule, 3 questions (6%)

Topics

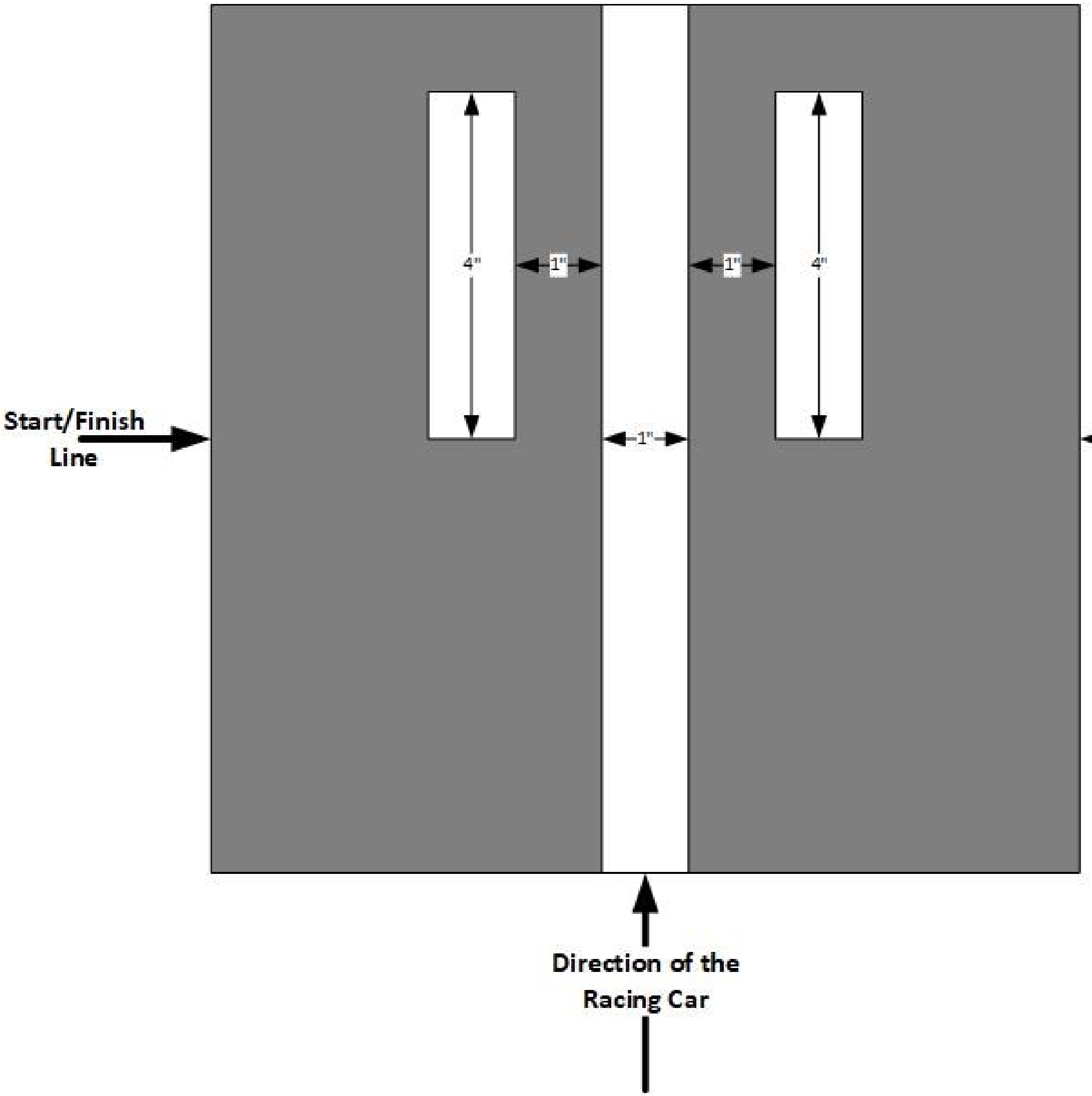
- Round 2 Discussion
- HW 3 discussion – due Tues 4/28
- Quiz 5
- Software Robustness- Observer
- Steering through Differential Braking

Round 2 Notes

Cones +2 second
Finish line:The start/finish line will be marked with two 4-inch-long segments of 1-inch-wide white tape that are parallel to the track with 1-inch spacing, as shown in the figure below.

The car must automatically stop within 6 feet of the finish line after finishing the race.

A penalty of 4 seconds will be added to the lap time for any car that does not automatically stop within the required region.



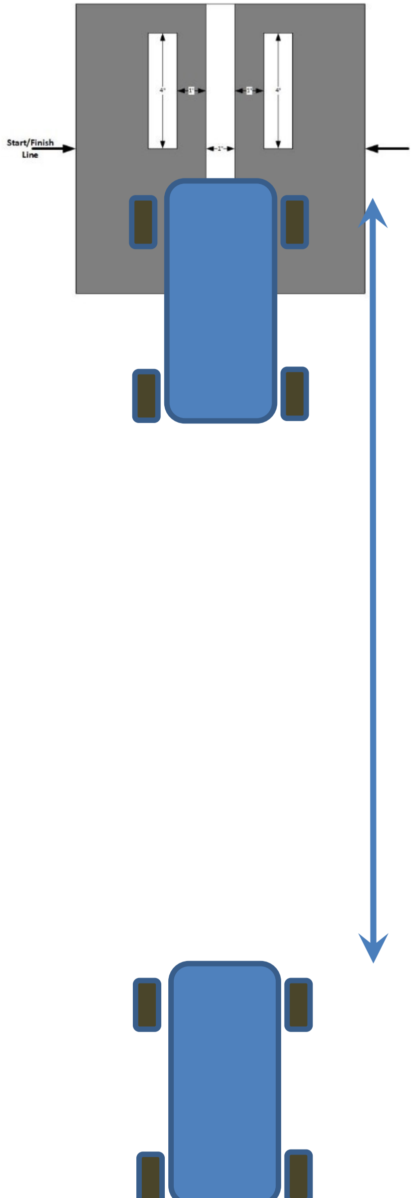
Round 2 Notes

1. Car can start in region shown (running start or avoid seeing stop line…) up to ``several feet” behind start/stop line

2. A running car can continue running for consecutive laps. If car is doing multiple laps without stopping, 4 second penalty is applied to intermediate laps.

The car must automatically stop within 6 feet of the finish line after finishing the race.

A penalty of 4 seconds will be added to the lap time for any car that does not automatically stop within the required region.



Permitted Start region

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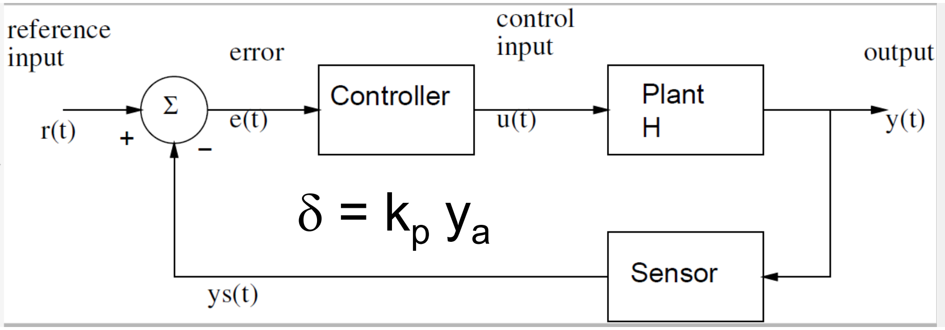
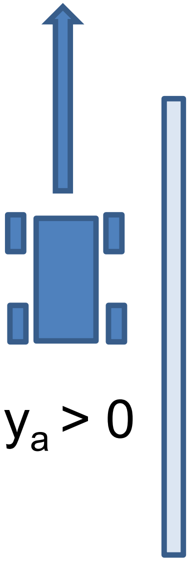
Circle at 10 m/s

Slow down due to steering sliding

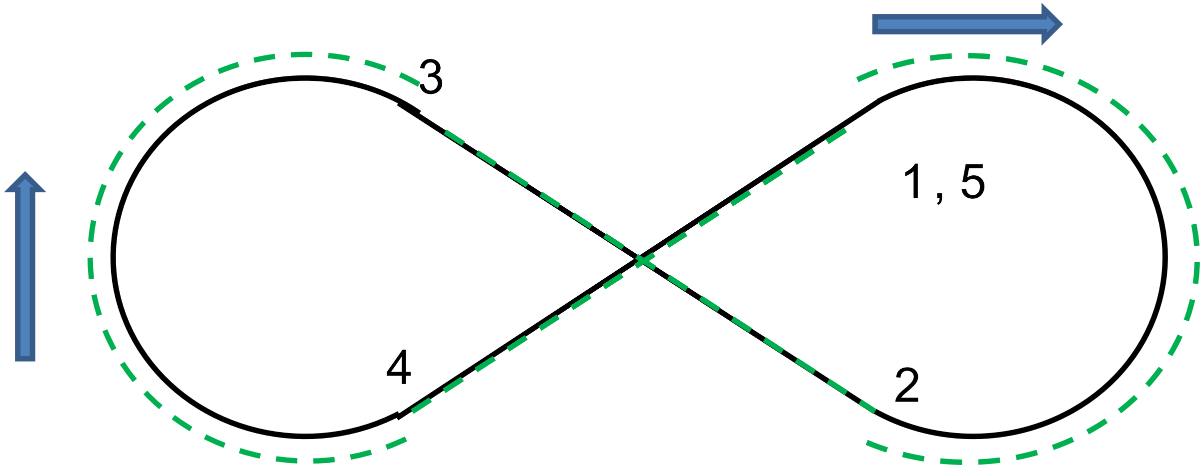
Feedforward using track memorization



$\delta = k_p\, y_a$



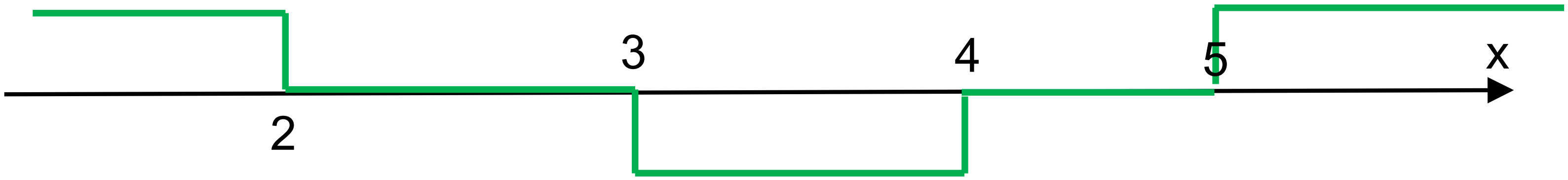
$y_a > 0$



Check signs … $r(x) = -\,e(x + v\,\Delta t)$ preview of turn

or $\delta = k_p\, y_a + (1 - a)\,\delta_{old}$

$r(x) =$



Topics

- Round 2 Discussion
- HW 3 discussion – due Tues 4/28
- Quiz 5 answer .pdf on bcourses
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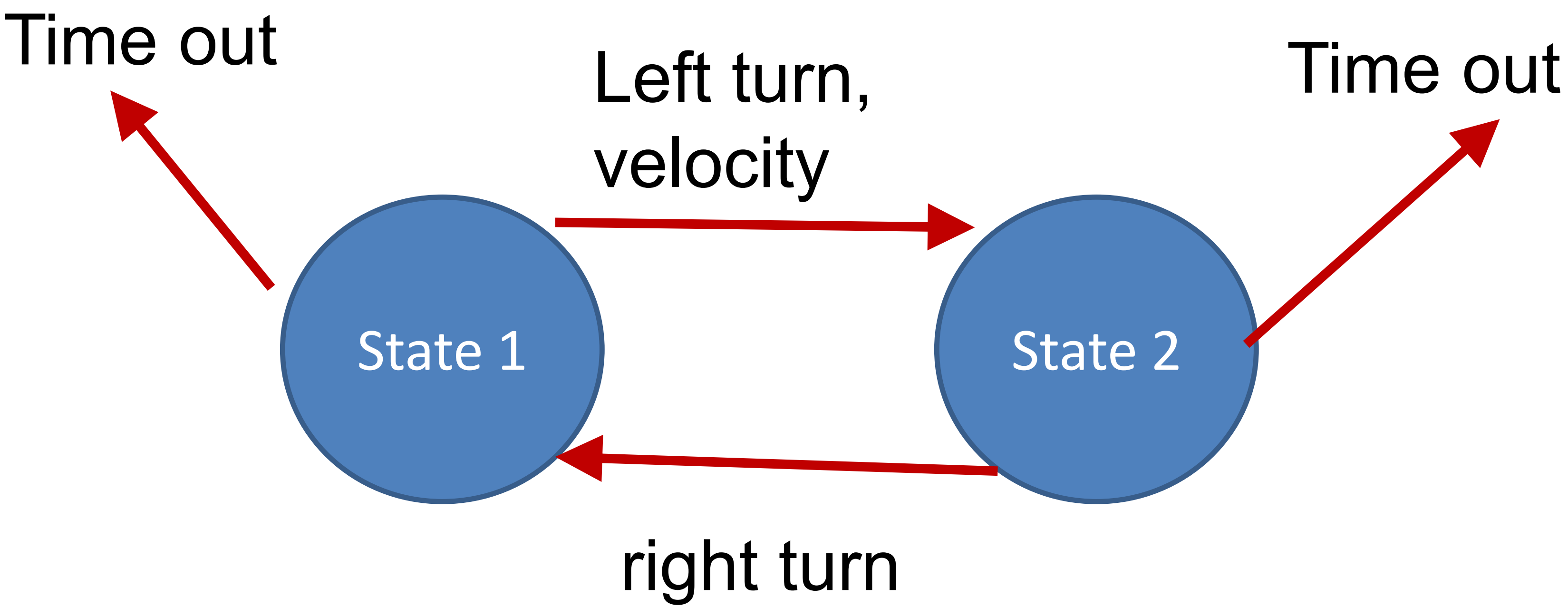
Software Robustness

- Checksums for bit rot
- Lost track detection
- Autocalibration at startup
  - (sanity check for steering angle vs line error)
  - AGC
- State Observer/estimator
- Discrete State observer
- Watch dog timer/computer operating properly COP

FSM Recognizer (generalized WDT)



Time out

Left turn,
velocity

Time out

State 1

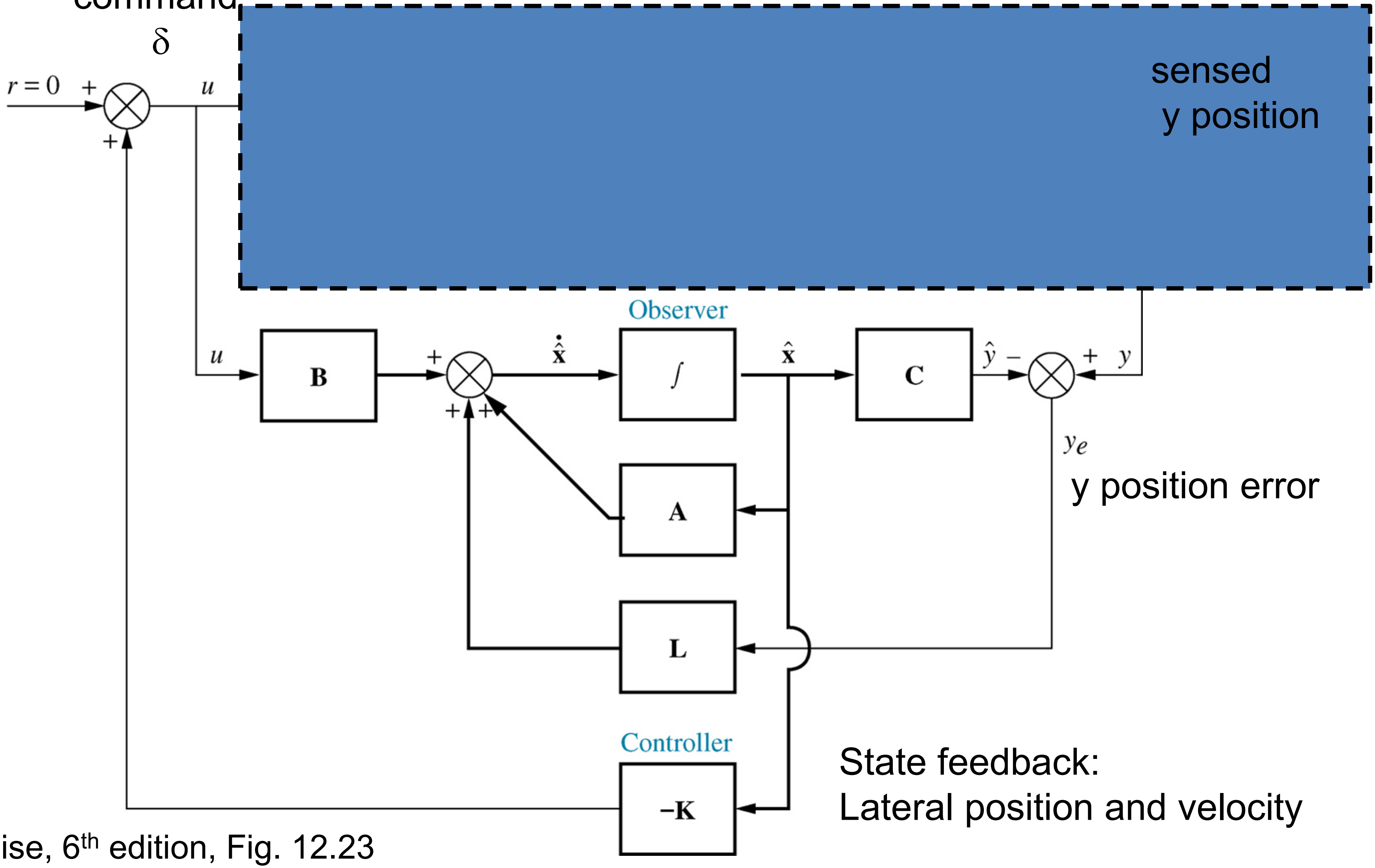
State 2

right turn

Software Robustness: Observer

(on board)

Steering command δ



sensed y position

y position error

State feedback:
Lateral position and velocity

N. Nise, 6th edition, Fig. 12.23

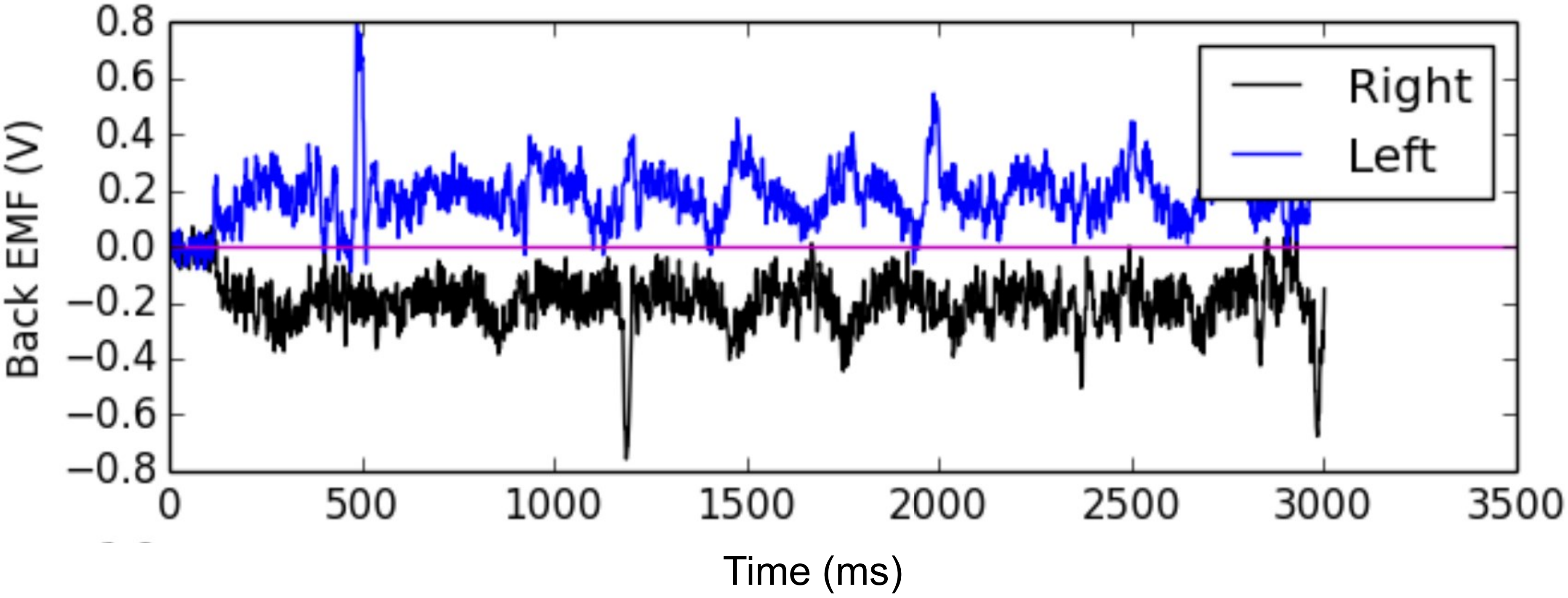
Digital Filtering

- Moving average
  - $y1[n] = (y[n-2]+y[n-1]+y[n])/3$
- Median filter (outlier rejection)
- Notch filter (mechanical vibration)
  - $y[n] = (x[n-2]+2x[n-1]+x[n])/4$

- Model based filtering (or Kalman filter)

Moving Average vs. Median Filter

Example: motor brush noise, back EMF measurement



{0,2,-1,4,0,2,1,1,20,1,0,2} ➔

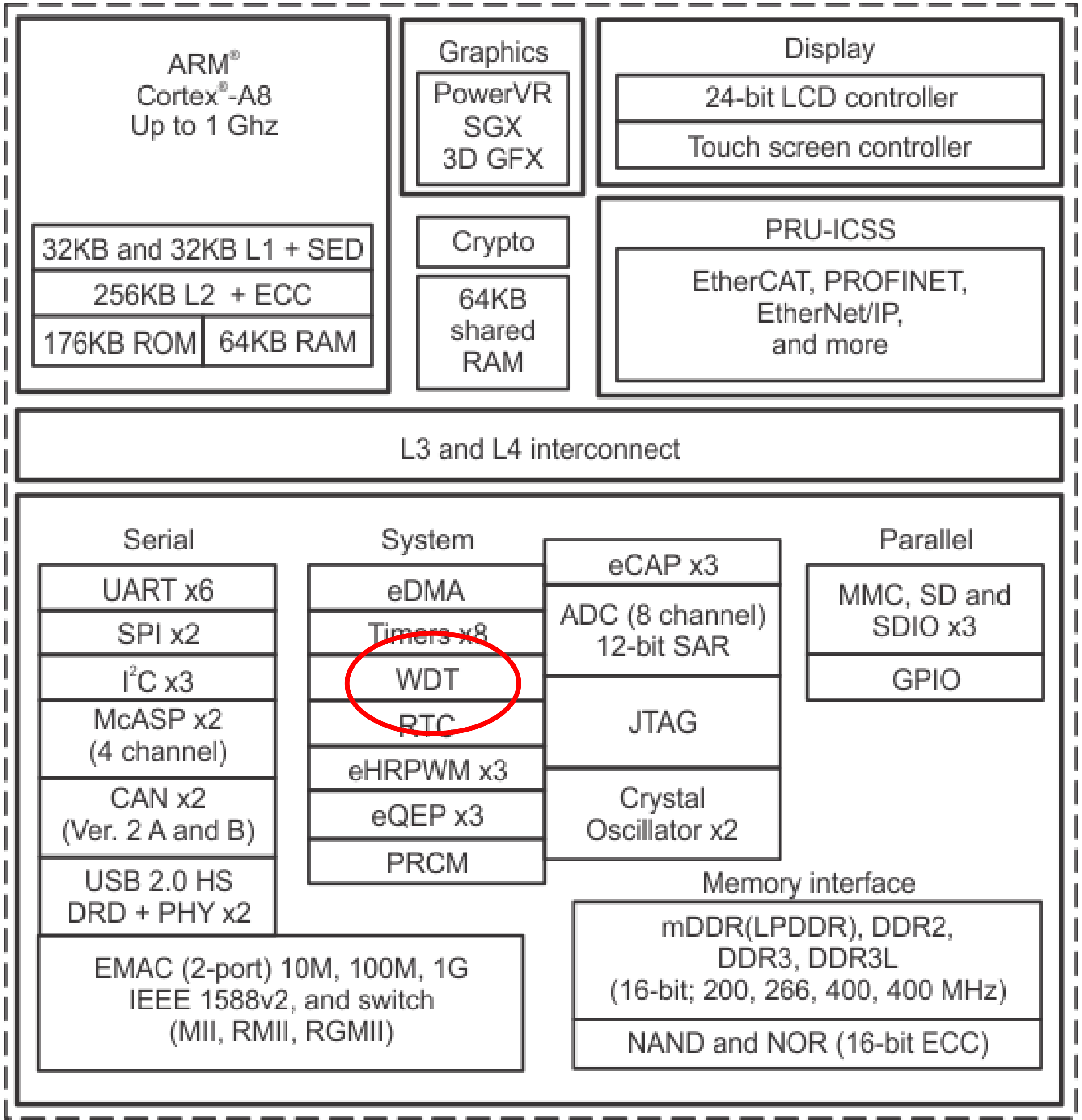
{0,2,-1,2,0,1,1,1,1,1} 3 element median filter

{0,2, 0.3,1.7, 2, 1,1.3, 7.3, 7.3, 7,1…} 3 elem MA

C.O.P. Watchdog timer

- Despite extensive software and hardware testing, faults will still occur in real devices. Even momentary noise spikes on a power supply can lock up a processor occasionally. Such events will occur on the power grid several times a year. Watchdog timers provide a last line of defense to prevent system failure with minimal hardware cost.
- https://developer.mbed.org/cookbook/WatchDog-Timer

ARM Cortex A8 Overview



ARM®
Cortex®-A8
Up to 1 Ghz

32KB and 32KB L1 + SED
256KB L2 + ECC
176KB ROM | 64KB RAM

Graphics
PowerVR SGX 3D GFX

Crypto

64KB shared RAM

Display
24-bit LCD controller
Touch screen controller

PRU-ICSS
EtherCAT, PROFINET, EtherNet/IP, and more

L3 and L4 interconnect

Serial
- UART x6
- SPI x2
- I^{2}C x3
- McASP x2 (4 channel)
- CAN x2 (Ver. 2 A and B)
- USB 2.0 HS DRD + PHY x2

System
- eDMA
- Timers x8
- WDT
- RTC
- eHRPWM x3
- eQEP x3
- PRCM
- eCAP x3
- ADC (8 channel) 12-bit SAR
- JTAG
- Crystal Oscillator x2

Parallel
- MMC, SD and SDIO x3
- GPIO

EMAC (2-port) 10M, 100M, 1G
IEEE 1588v2, and switch
(MII, RMII, RGMII)

Memory interface
- mDDR(LPDDR), DDR2, DDR3, DDR3L (16-bit; 200, 266, 400, 400 MHz)
- NAND and NOR (16-bit ECC)

Beaglebone Blue
TI **Sitara™ AM335x Processors**
ARM Cortex A8
4GB Flash
512 MB RAM
32 bit ARM 7 core
1 GHz
A/D
3x SPI
Timers
WiFi
USB
microSD card

Watch Dog Timer

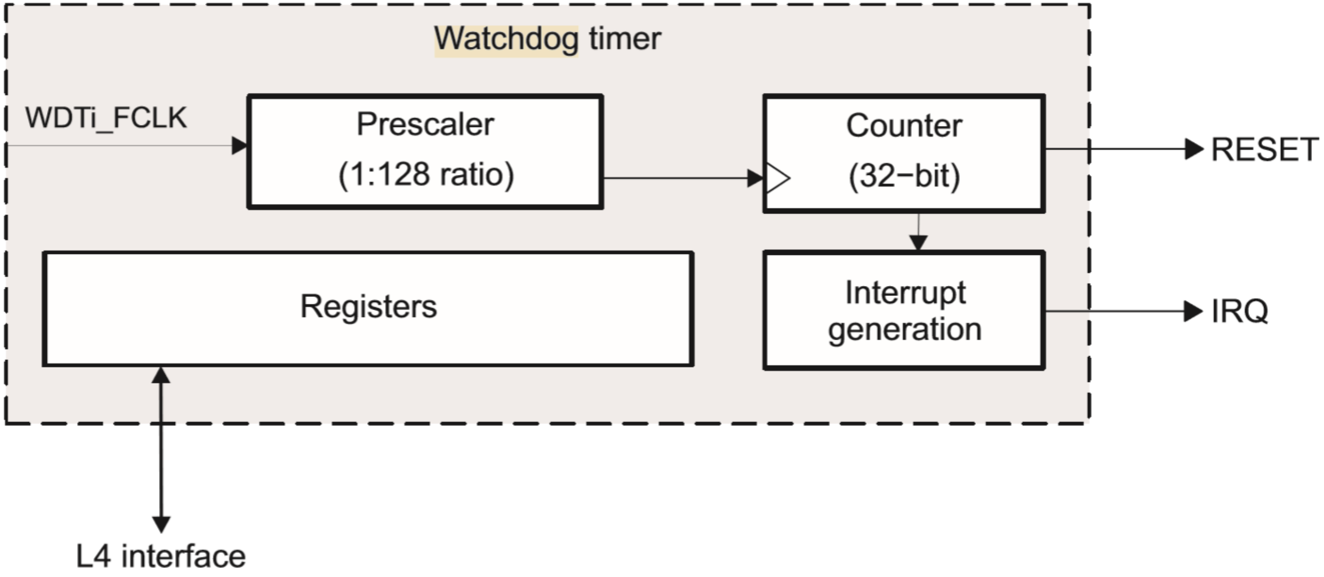
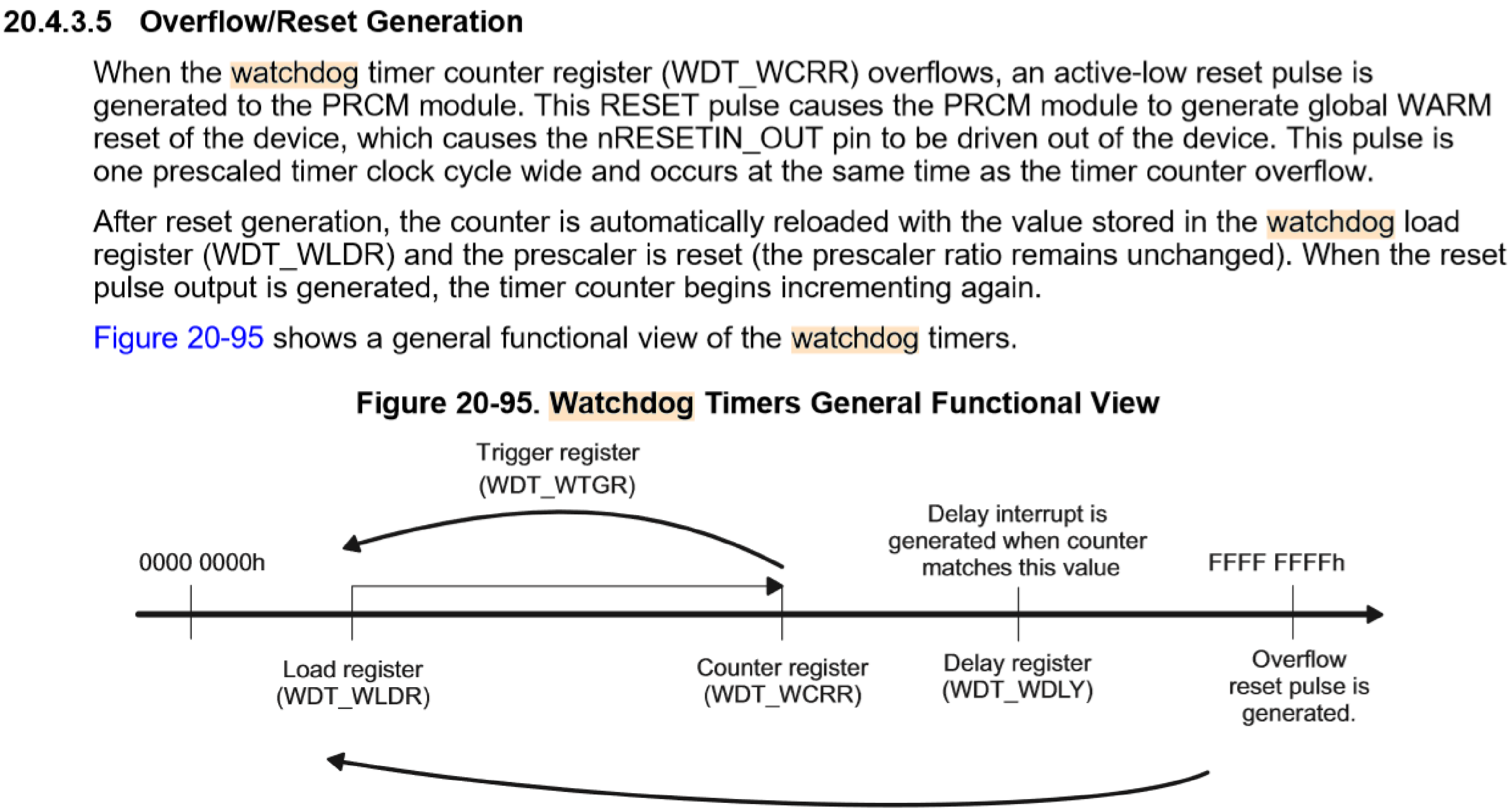


Figure 20-94. 32-Bit Watchdog Timer Functional Block Diagram

Watchdog reset



20.4.3.5 Overflow/Reset Generation

When the watchdog timer counter register (WDT_WCRR) overflows, an active-low reset pulse is generated to the PRCM module. This RESET pulse causes the PRCM module to generate global WARM reset of the device, which causes the nRESETIN_OUT pin to be driven out of the device. This pulse is one prescaled timer clock cycle wide and occurs at the same time as the timer counter overflow.

After reset generation, the counter is automatically reloaded with the value stored in the watchdog load register (WDT_WLDR) and the prescaler is reset (the prescaler ratio remains unchanged). When the reset pulse output is generated, the timer counter begins incrementing again.

Figure 20-95 shows a general functional view of the watchdog timers.

Figure 20-95. Watchdog Timers General Functional View

20.4.3.8 Start/Stop Sequence for Watchdog Timers (Using the WDT_WSPR Register)

To start and stop a watchdog timer, access must be made through the start/stop register (WDT_WSPR) using a specific sequence.
To disable the timer, follow this sequence:
1. Write XXXX AAAAh in WDT_WSPR.
2. Poll for posted write to complete using WDT_WWPS.W_PEND_WSPR.
3. Write XXXX 5555h in WDT_WSPR.
4. Poll for posted write to complete using WDT_WWPS.W_PEND_WSPR.

To enable the timer, follow this sequence:
1. Write XXXX BBBBh in WDT_WSPR.
2. Poll for posted write to complete using WDT_WWPS.W_PEND_WSPR.
3. Write XXXX 4444h in WDT_WSPR.
4. Poll for posted write to complete using WDT_WWPS.W_PEND_WSPR.

All other write sequences on the WDT_WSPR register have no effect on the start/stop feature of the module.

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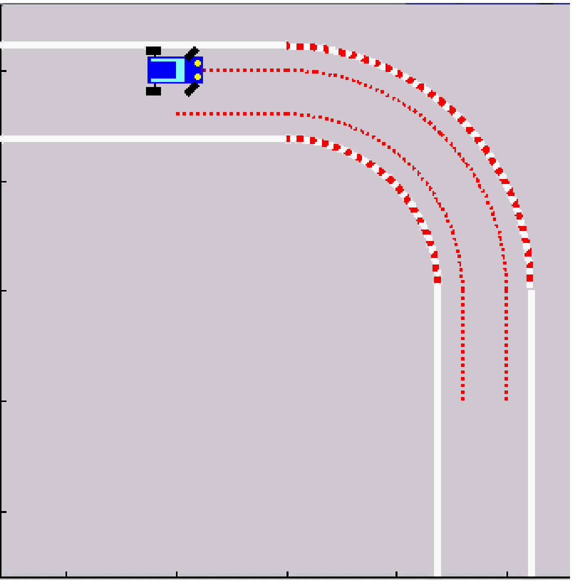
Steering References (on web page)

- Vehicle Dynamics and Control During Abnormal Driving

http://soliton.ae.gatech.edu/people/dcsl/research-abnormal.html

Prof. Panagiotis Tsiotras, Georgia Tech



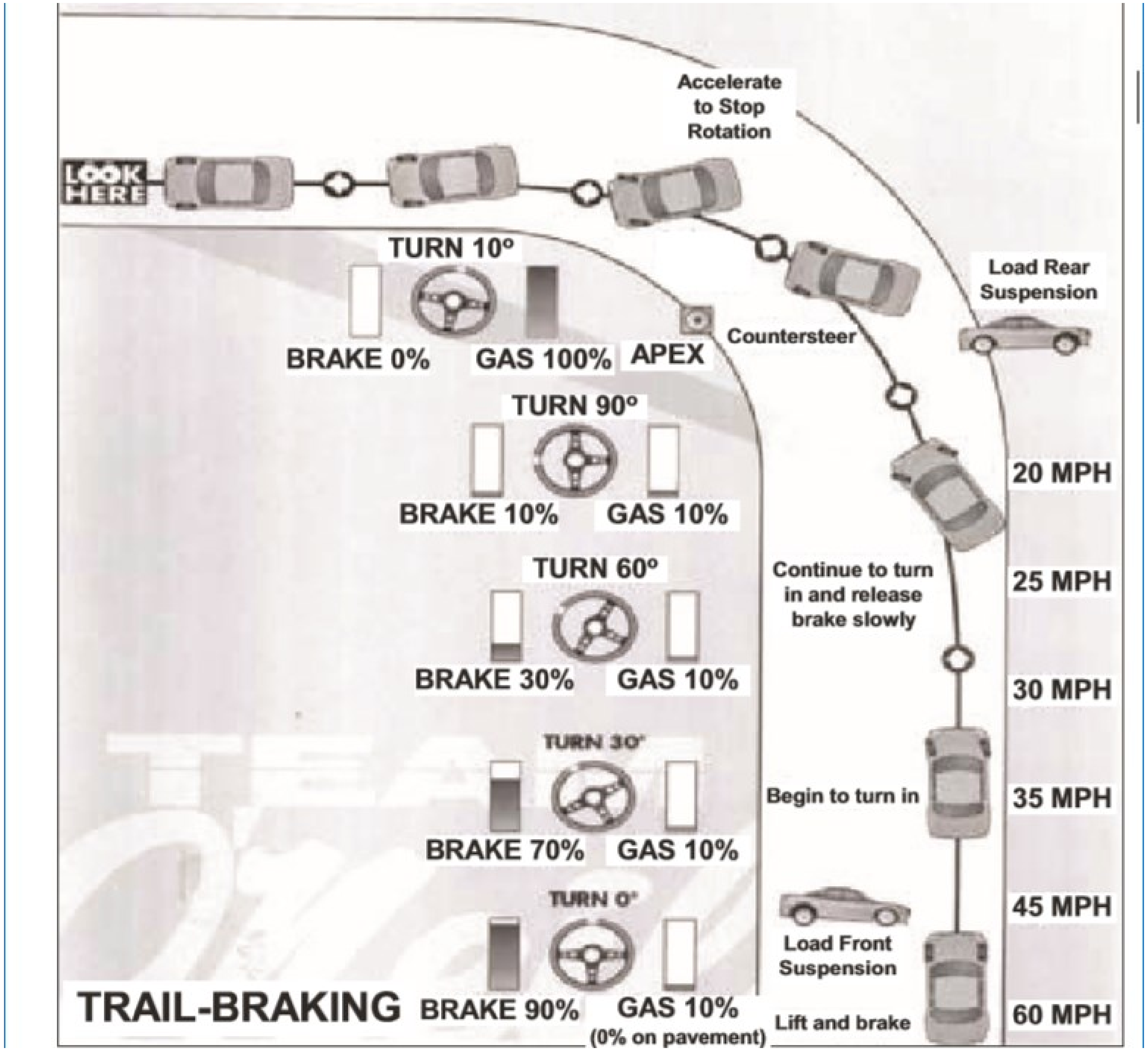
http://soliton.ae.gatech.edu/people/dcsl/movies/skidding.avi

http://soliton.ae.gatech.edu/people/dcsl/movies/TrailBraking.avi

Steering References (on web page)

- Vehicle Dynamics and Control During Abnormal Driving (Georgia Tech)
- Velenis, E., Tsiotras, P., and Lu, J., "Aggressive Maneuvers on Loose Surfaces: Data Analysis and Input Parameterization,’’ 15th IEEE Mediterranean Control Conference, June 26-29, Athens, Greece.
- Velenis, E., Tsiotras, P., and Lu, J., "Modeling Aggressive Maneuvers on Loose Surfaces: The Cases of Trail-Braking and Pendulum-Turn,’’ European Control Conference, Kos, Greece, July 2-5, 2007.
- Some nice turning simulation (Georgia Tech): (video 1) (video 2)
- Baffet, G. Charara, A. Dherbomez, G. ‘‘An Observer of Tire Road Forces and Friction for Active Security Vehicle Systems’’ Mechatronics, IEEE/ASME Transactions on Publication Date: Dec. 2007 Volume: 12, Issue: 6 On page(s): 651-661
- Tseng, H.E. Ashrafi, B. Madau, D. Allen Brown, T. Recker, D. ‘‘The development of vehicle stability control at Ford’’ Mechatronics, IEEE/ASME Transactions on Publication Date: Sep 1999 Volume: 4, Issue: 3 On page(s): 223-234
- T. Pilutti, G. Ulsoy, and D. Hrovat, ‘‘Vehicle steering intervention through differential braking,’’ Proc. American Control Conf. Seattle, Wash. June 1995.
- Brennan, S. Alleyne, A. ‘‘Using a scale testbed: Controller design and evaluation’’ Control Systems Magazine, IEEE Publication Date: Jun 2001 Volume: 21, Issue: 3 On page(s): 15-26
- Brennan, S. Alleyne, A. ‘‘The Illinois Roadway Simulator: a mechatronic testbed for vehicle dynamics and control,’’ Mechatronics, IEEE/ASME Transactions on Publication Date: Dec 2000 Volume: 5, Issue: 4 On page(s): 349-359
- Chankyu Lee K. Hedrick Kyongsu Yi , ‘‘Real-time slip-based estimation of maximum tire-road friction coefficient,’’ Mechatronics, IEEE/ASME Transactions on Publication Date: June 2004
- Han-Shue Tan; Guldner, J.; Patwardhan, S.; Chieh Chen; and others. Development of an automated steering vehicle based on roadway magnets-a case study of mechatronic system design. IEEE/ASME Transactions on Mechatronics, Sept. 1999, vol.4, (no.3):258-72.
- Guldner, J.; Sienel, W.; Han-Shue Tan; Ackermann, J.; and others. Robust automatic steering control for look-down reference systems with front and rear sensors. IEEE Transactions on Control Systems Technology, Jan. 1999, vol.7, (no.1):2-11.
- Patwardhan, S.; Han-Shue Tan; Guldner, J. A general framework for automatic steering control: system analysis. Proceedings of 16th American CONTROL Conference, Albuquerque, NM, USA, 4-6 June 1997). Evanston, IL, USA: American Autom. Control Council, 1997. p. 1598-602 vol.3.
- Patwardhan, S.; Han-Shue Tan; Guldner, J.; Tomizuka, M. Lane following during backward driving for front wheel steered vehicles. Proceedings of 16th American CONTROL Conference, Albuquerque, NM, USA, 4-6 June 1997). Evanston, IL, USA: American Autom. Control Council, 1997. p. 3348-53 vol.5.
- Guldner, J.; Han-Shue Tan; Patwardhan, S. Study of design directions for lateral vehicle control. Proceedings of the 36th IEEE Conference on Decision and Control, San Diego, CA, USA, 10-12 Dec. 1997). New York, NY, USA: IEEE, 1997. p. 4732-7 vol.5.
- Analysis of automatic steering control for highway vehicles with look-down lateral reference systems. Vehicle System Dynamics, Oct. 1996, vol.26, (no.4):243-69.

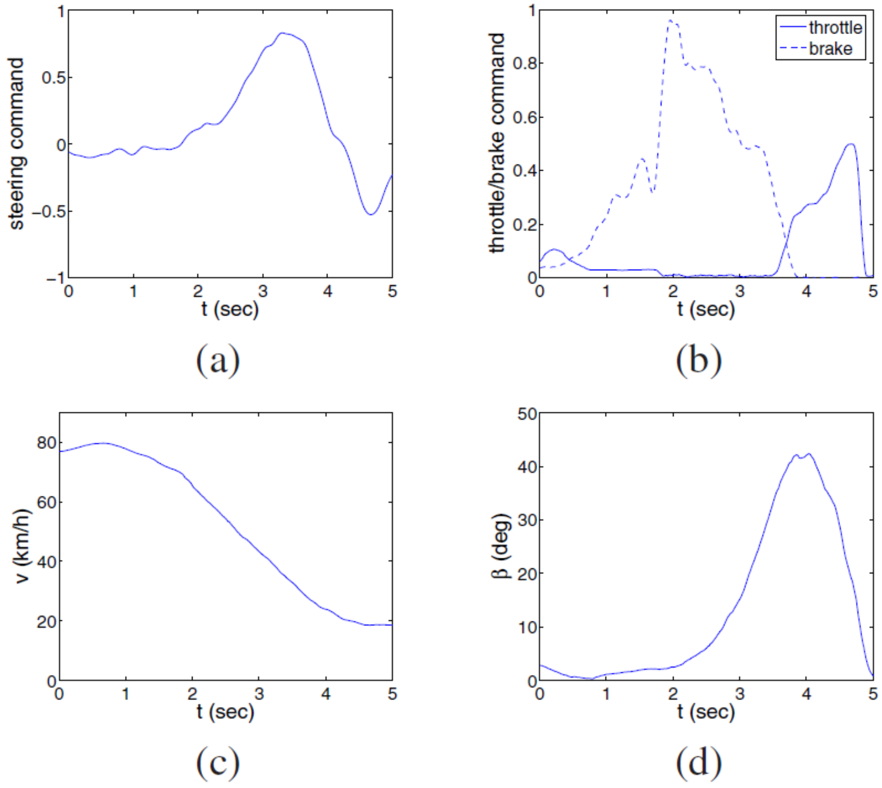
Steering: Trail Braking Maneuver (Rally car)



1. Brake hard, drive straight (increased load on front wheels)
2. Increase steering command, reduce braking (oversteering)
3. Decrease steering, counter steers, apply throttle to stabilize

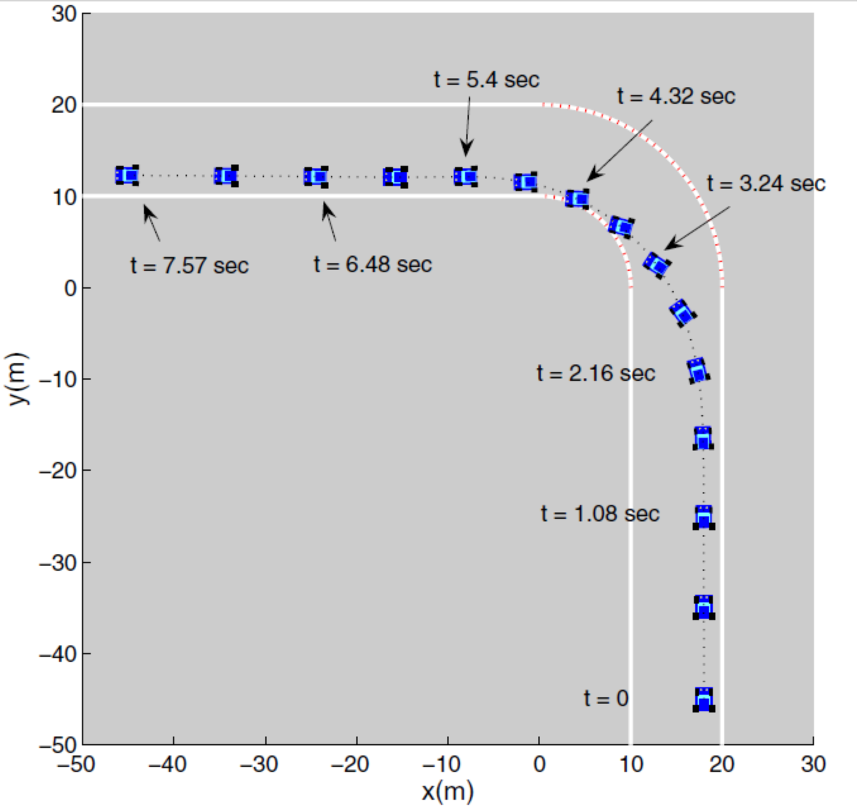
Velenis, E., Tsiotras, P., and Lu, J., “Modelling Aggressive Maneuvers on Loose Surfaces'' European *Control Conference*, 2007.

Steering: Trail Braking Maneuver



(a) (b) (c) (d)

Fig. 3. Trail-Braking maneuver experimental data: (a) Normalized steering command; (b) Normalized throttle and braking commands; (c) Vehicle speed; (d) Vehicle slip angle.



1. Brake hard, drive straight (increased load on front wheels)
2. Increase steering command, reduce braking (oversteering)
3. Decrease steering, counter steer, apply throttle to stabilize

Velenis, E., Tsiotras, P., and Lu, J., "Aggressive Maneuvers on Loose Surfaces: Data Analysis and Input Parameterization," *15th IEEE Mediterranean Control Conference*, June 26-29, 2007 Athens, Greece.

Steering: Trail Braking Maneuver

- Vehicle Dynamics and Control During Abnormal Driving

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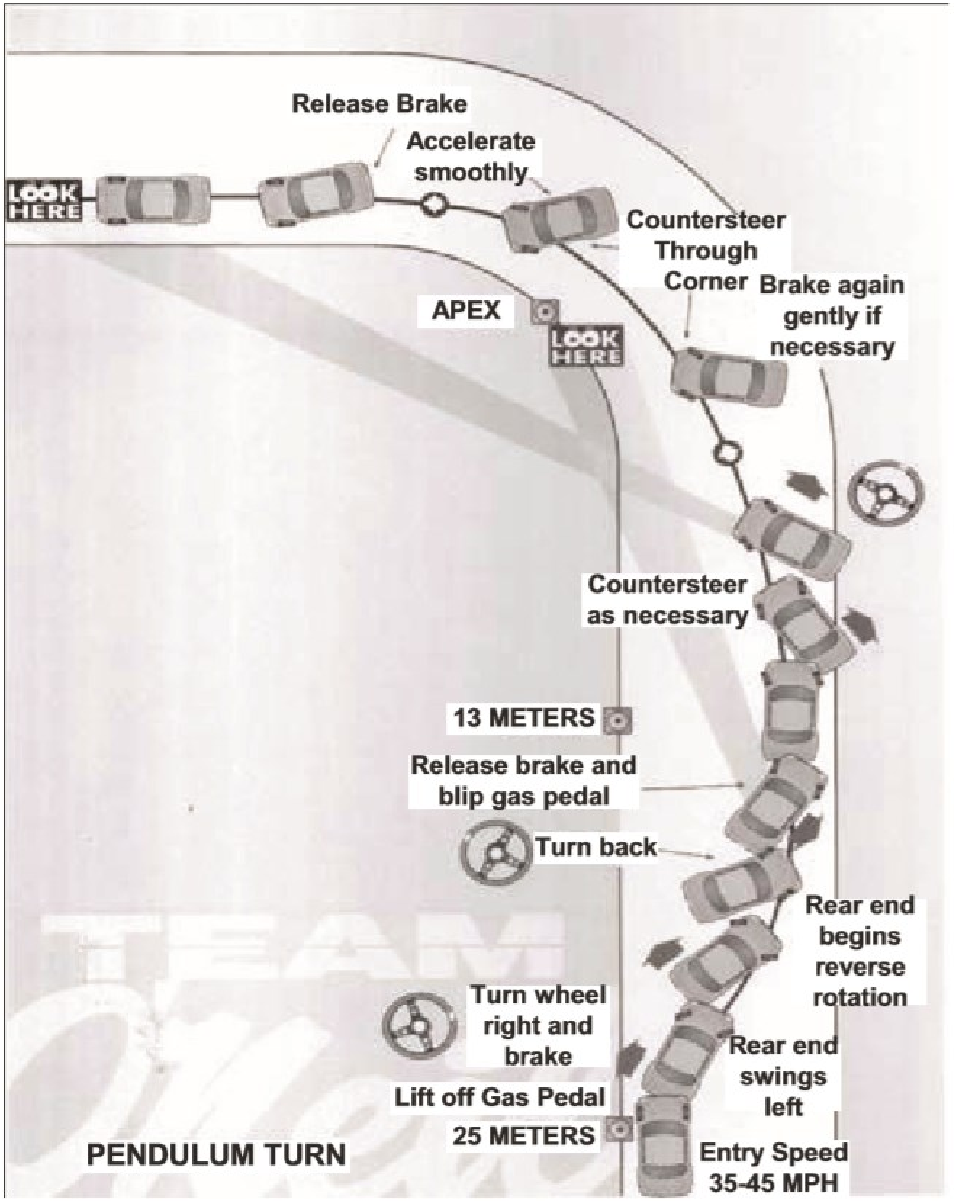
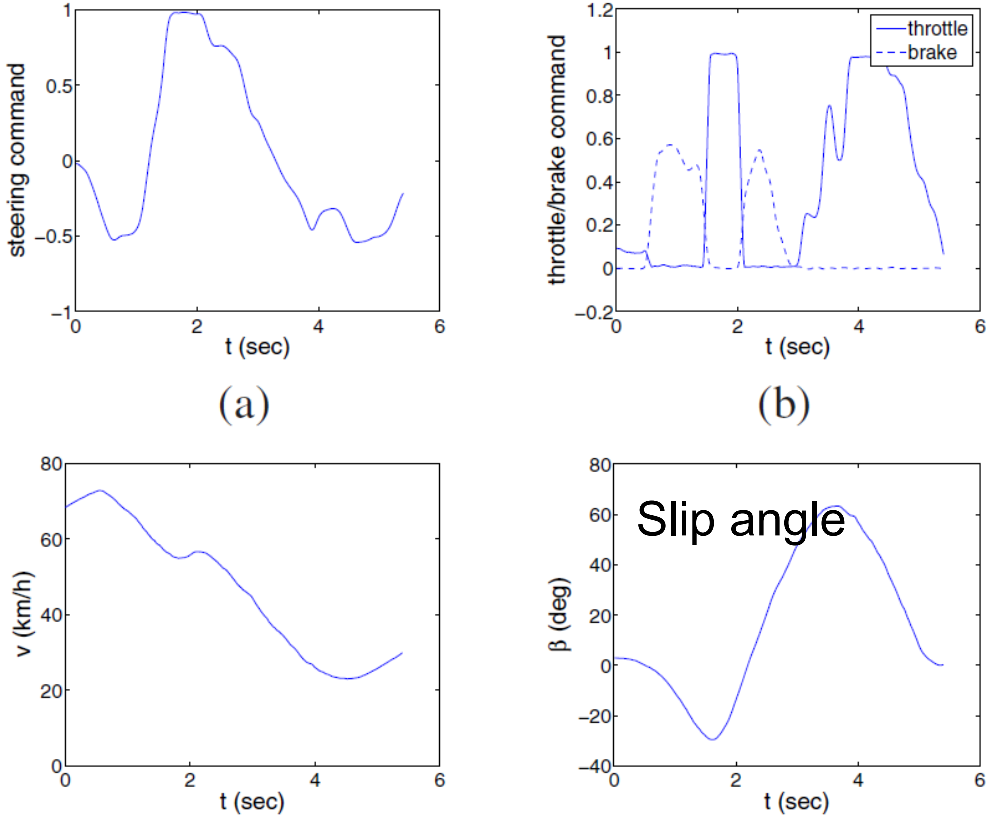
Steering: Pendulum Turn Maneuver (Sim)

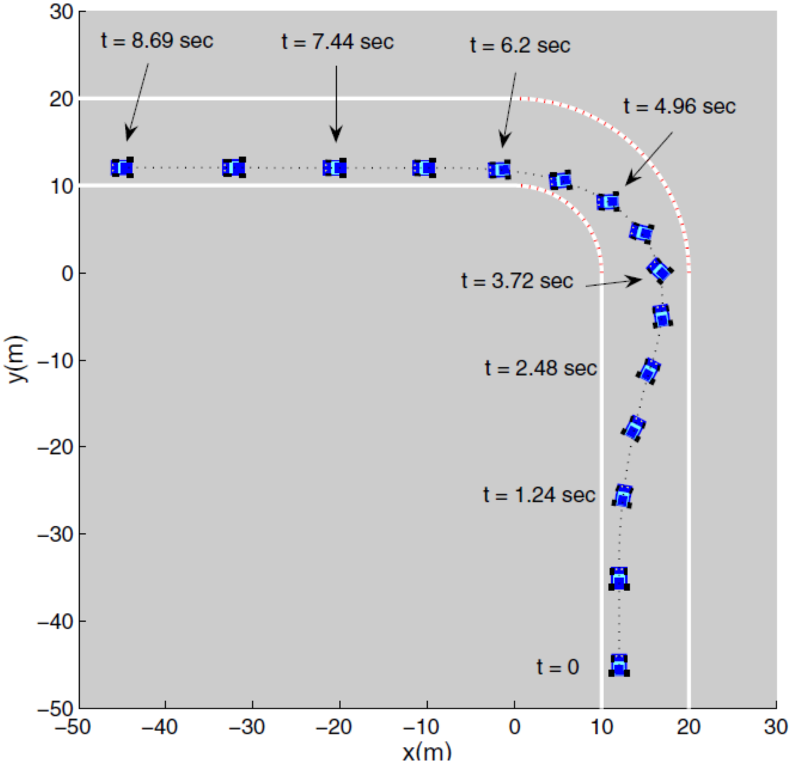


Steering: Pendulum Turn Maneuver (Sim)



(a) (b)

(c) (d)



1. Turn opposite while applying brakes (increased load on front wheels, oversteering)
2. Throttle blip to damp rotation
3. steer in direction of turn and apply brakes to rotate fast
4. Decrease steering command, counter-steers, applies throttle to stabilize

Velenis, E., Tsiotras, P., and Lu, J., "Aggressive Maneuvers on Loose Surfaces: Data Analysis and Input Parameterization," *15th IEEE Mediterranean Control Conference*, June 26-29, 2007 Athens, Greece.

http://soliton.ae.gatech.edu/people/dcsl/movies/PendulumTurn.avi

Vehicle Stability through Differential Braking

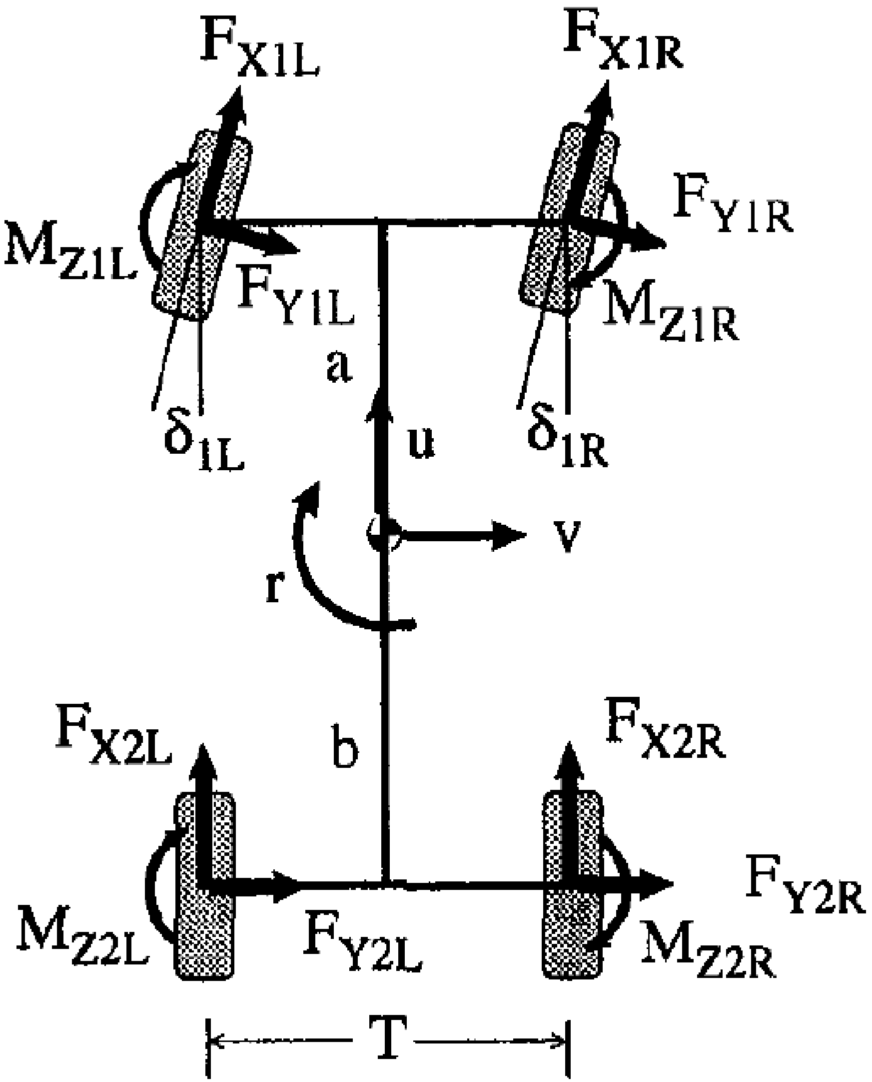


Fig. 1 Seven DoF vehicle model

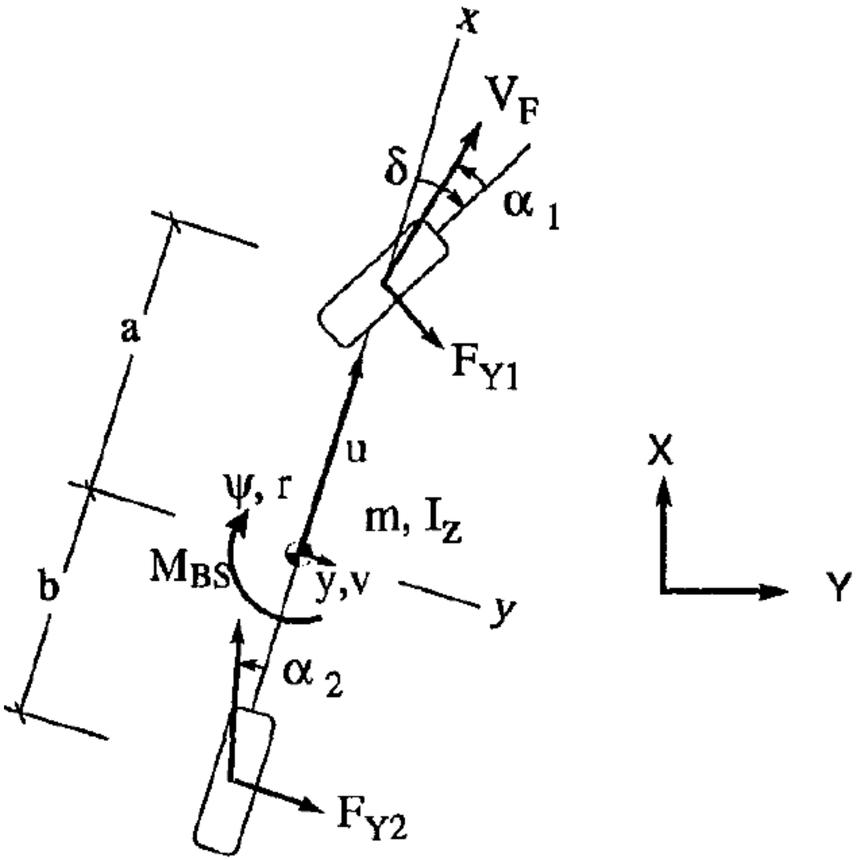
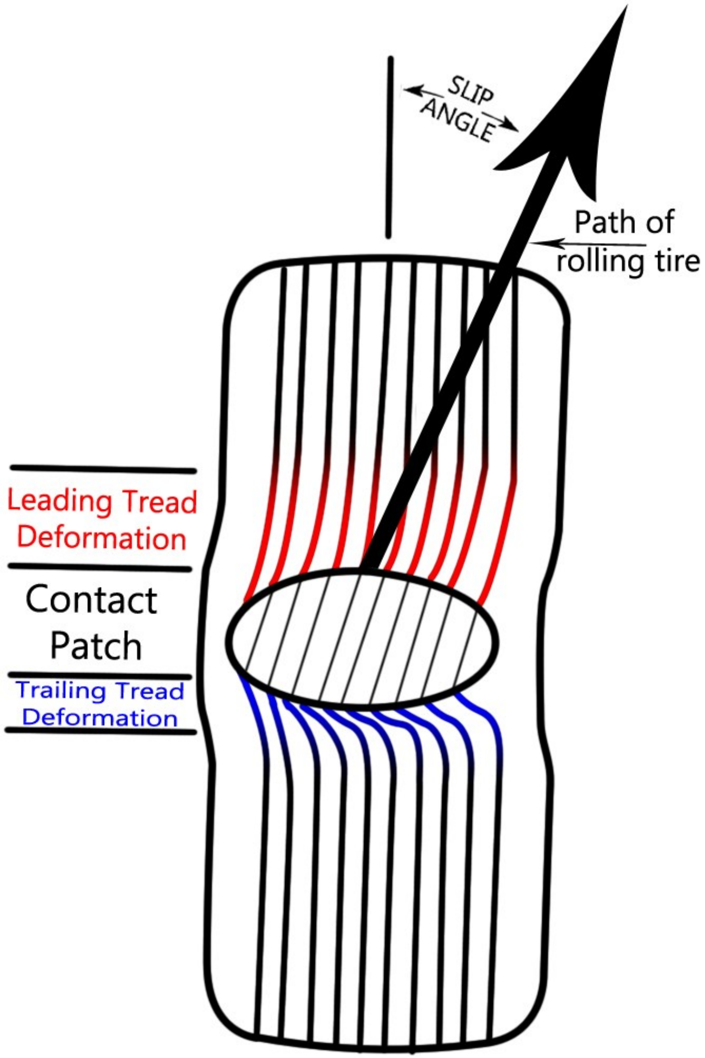


Fig. 2 Two DoF model

- T. Pilutti, G. Ulsoy, and D. Hrovat, "Vehicle steering intervention through differential braking," Proc. American Control Conf. Seattle, Wash. June 1995.

Tire Slip Angle



http://technicalf1explained.blogspot.com/2012/10/f1-tirespart-2.html