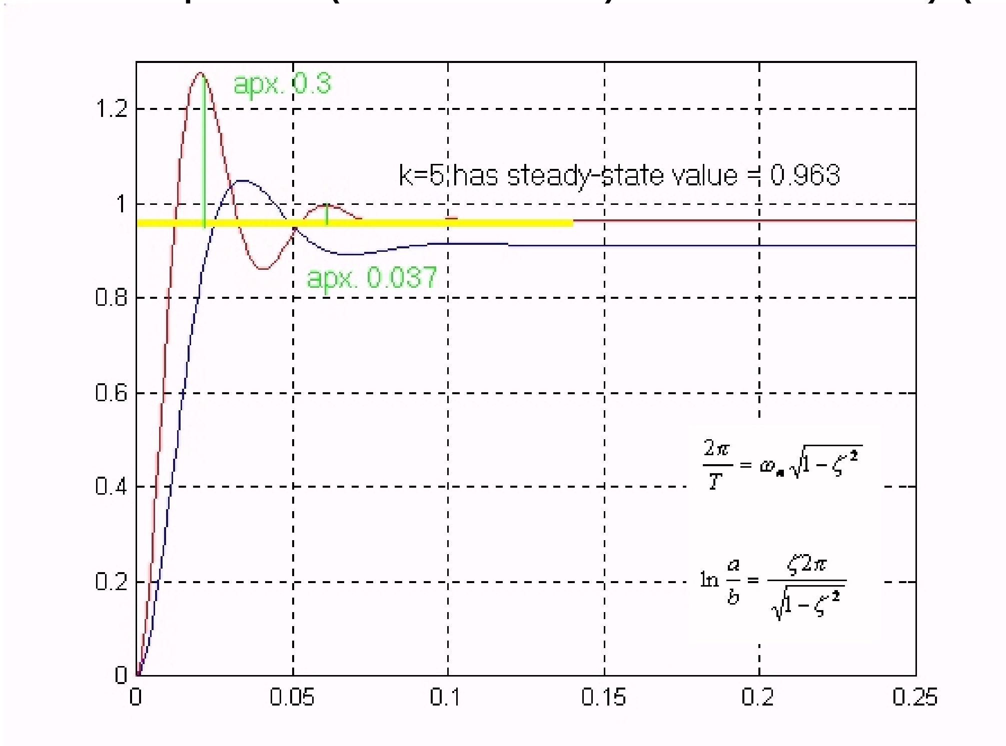
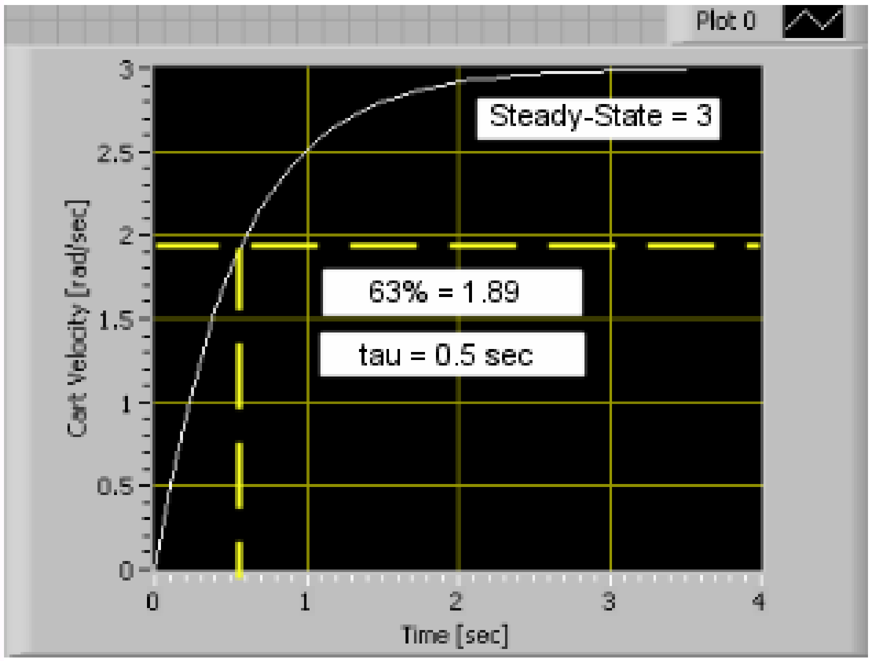
System ID

MEM 639 Real-Time Microcomputer Control 1

Objective: System Identification

System ID attempts to capture a plant's characteristics such as transient response (i.e. rise time) and its stability (steady-state





Typical 2nd Order Response

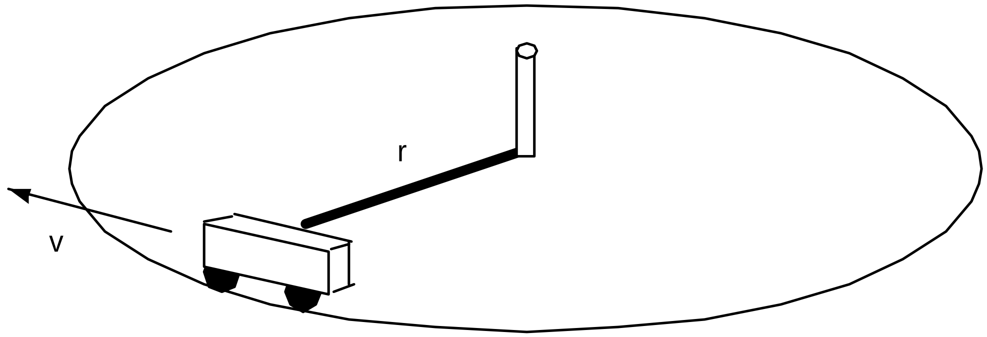
- Car shock absorbers
- Pneumatic pistons
- Economic systems

Typical 1st Order Response

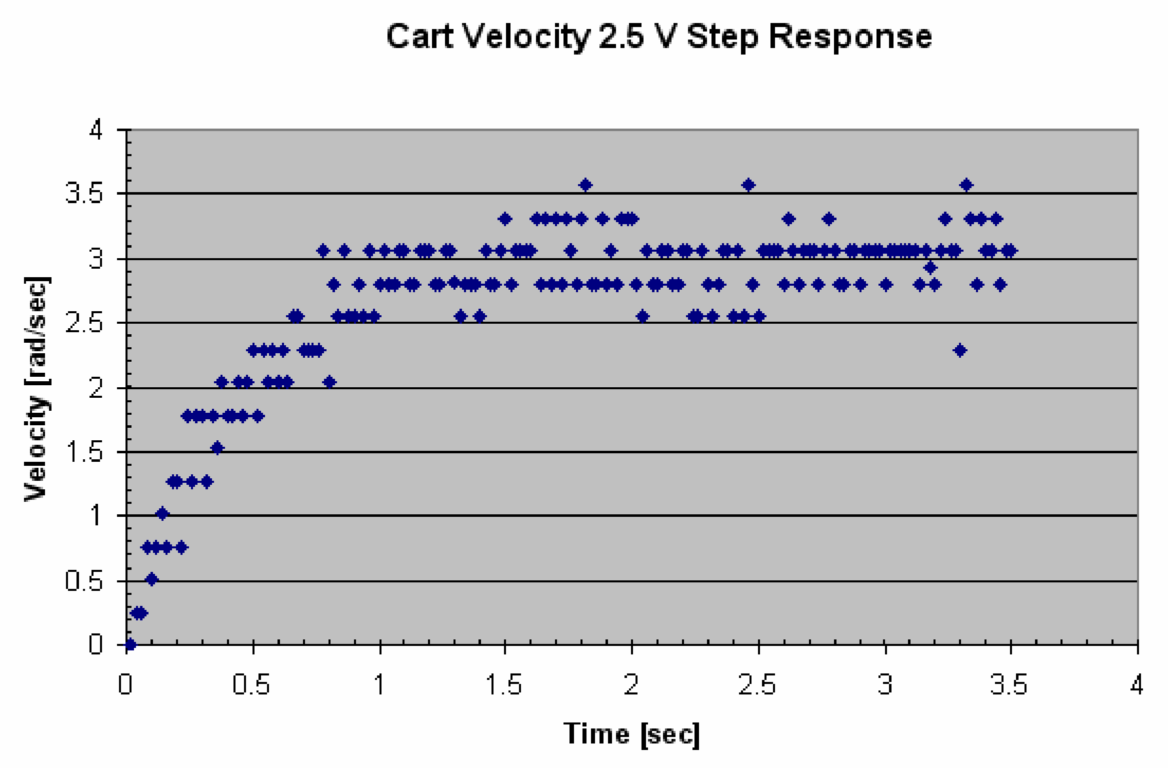
- DC motors
- Damped hydraulics
-

Grandmother Explanation?

MEM 639 System: Motorized Tethered Cart



- Pivot encoder records angle
- Sample angle every 20 ms
- Register for velocity calculations



- 2.5 Volt step command
- 3 m/s steady-state velocity
- 0.5 sec time constant

Voltage input $f(t)$ to the cart motor, yields velocity output $y(t)$

Consequently have:

$$\tau \frac{dy}{dt} + y = k \cdot f(t) \tag{1}$$

where τ is the time constant and k is the steady-state gain (to be determined)

The Laplace form of (1) yields:

$$Y(\tau s + 1) = k \cdot F \tag{2}$$

The input-output transfer function becomes

$$\frac{Y(s)}{F(s)} = \frac{k}{1 + \tau s} \tag{3}$$

Also, the solution to the first-order differential equation given in (1) is

$$y(t) = Y_{ss}\left(1 - e^{-t/\tau}\right) \tag{4}$$

To calculate the steady-state gain, apply a step input $f(t) = Au(t)$

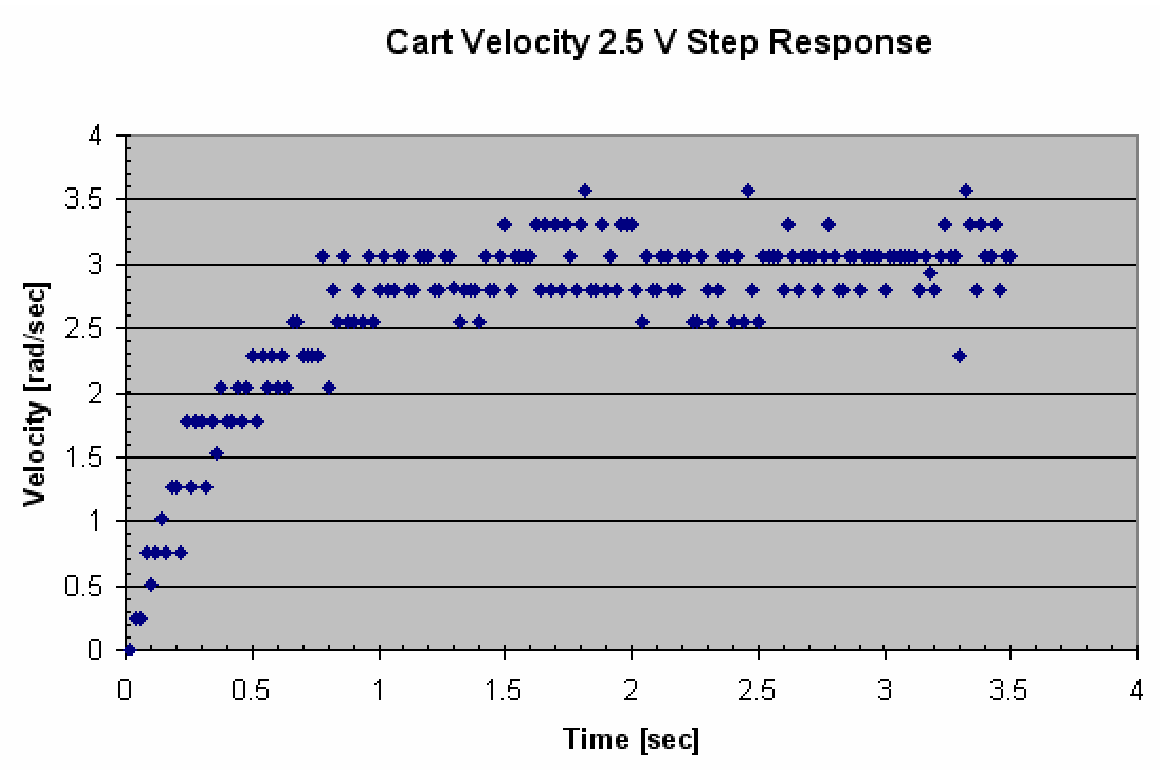
where A is a constant

At steady-state, with step input, (1) becomes:

$$\tau \frac{dy}{dt} + y = k \cdot f(t) \quad \text{(} \tfrac{dy}{dt} \to 0,\ y \to Y_{ss} \text{)}$$

or

$$k = \frac{Y_{ss}}{A} = \frac{\text{Steady State Velocity}}{\text{Step Input Voltage}} = \frac{[\text{rad/s}]}{[\text{Volts}]} \qquad (5)$$



Step response for $A = 2.5$ Volts

Eyeballing, observe that:

$$Y_{ss} = 3 \text{ rad/s}$$

Hence:

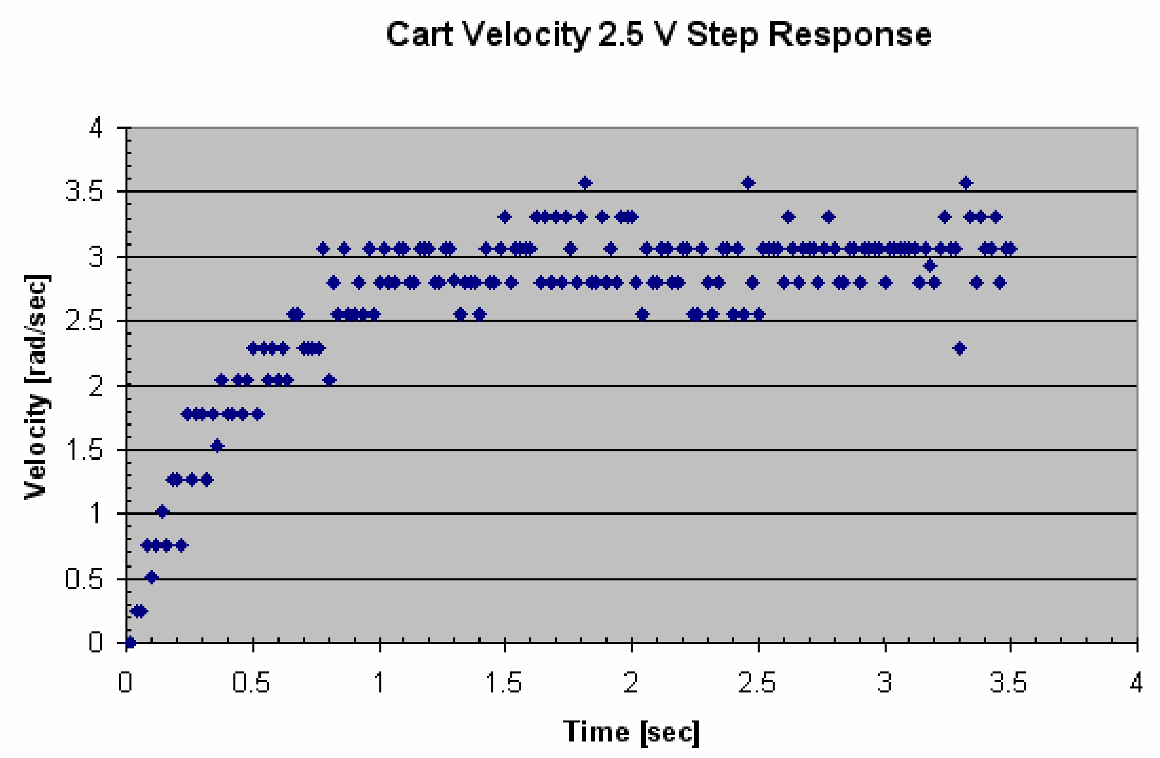
$$k = \frac{Y_{ss}}{A} = \frac{3 \text{ rad/sec}}{2.5 \text{ Volts}} = 1.20 \text{ rad/Volts} \cdot \text{s}$$

Recall (4)

$$y(t) = Y_{ss}\left(1 - e^{-t/\tau}\right)$$

at $t = \tau$

$$y(\tau) = Y_{ss}\left(1 - e^{-1}\right) = 0.632 \cdot Y_{ss}$$



63% value is about $Y_{ss} = 1.89\,\text{rad/s}$

Hence

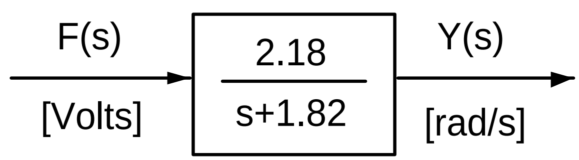
$$\tau = 0.55\,\text{sec}$$

Thus from (3) the open-loop transfer function due to step input of 2.5 Volts yields:

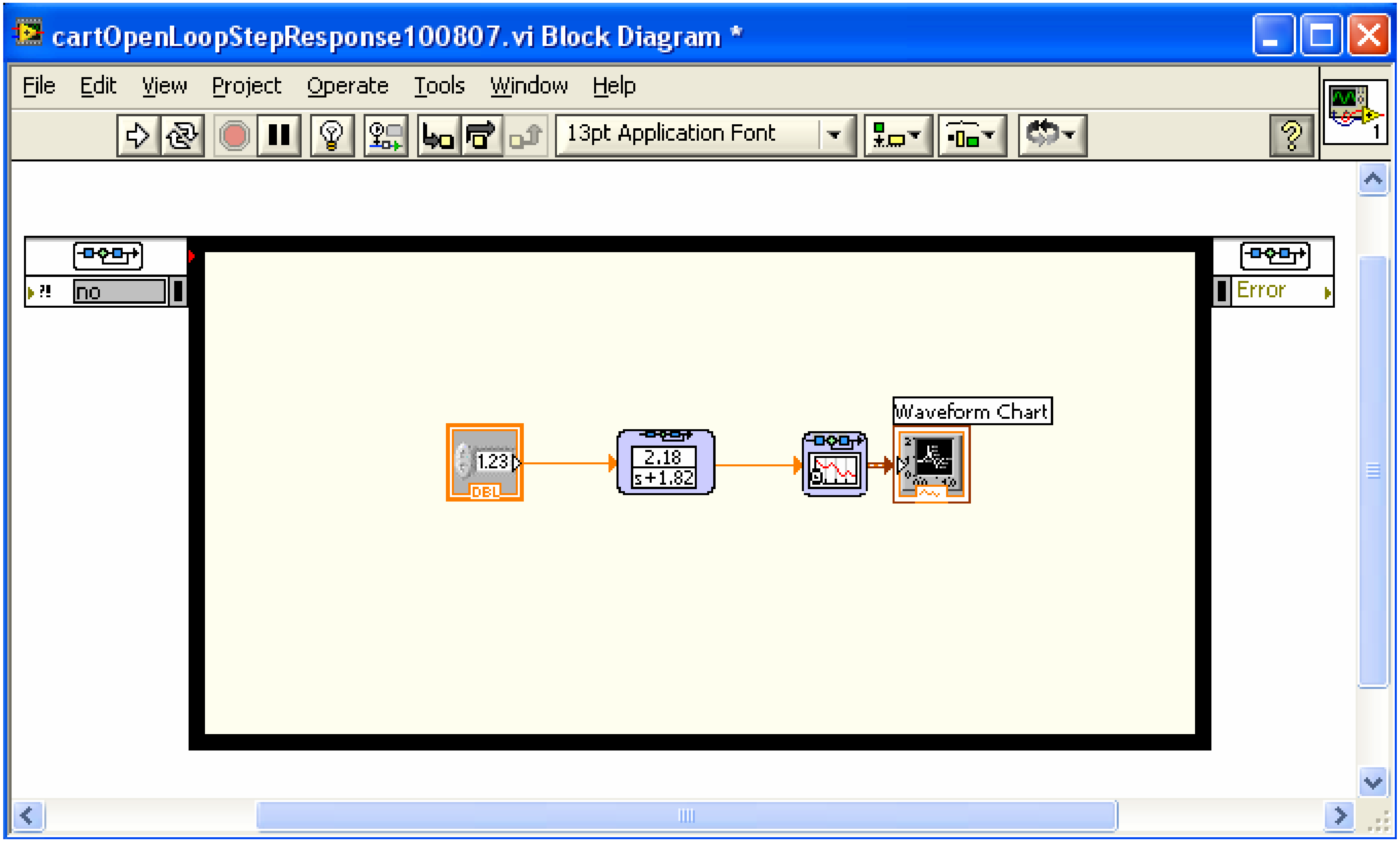
$$\frac{Y(s)}{F(s)} = \frac{k}{1+\tau s} \quad \text{where} \quad \tau = 0.55\,\text{sec} \quad \text{and} \quad k = 1.20\,\text{rad/V}\cdot\text{s}$$

$$\frac{Y(s)}{F(s)} = \frac{1.20}{1+0.55\cdot s} = \frac{2.18}{s+1.82} \qquad (6)$$

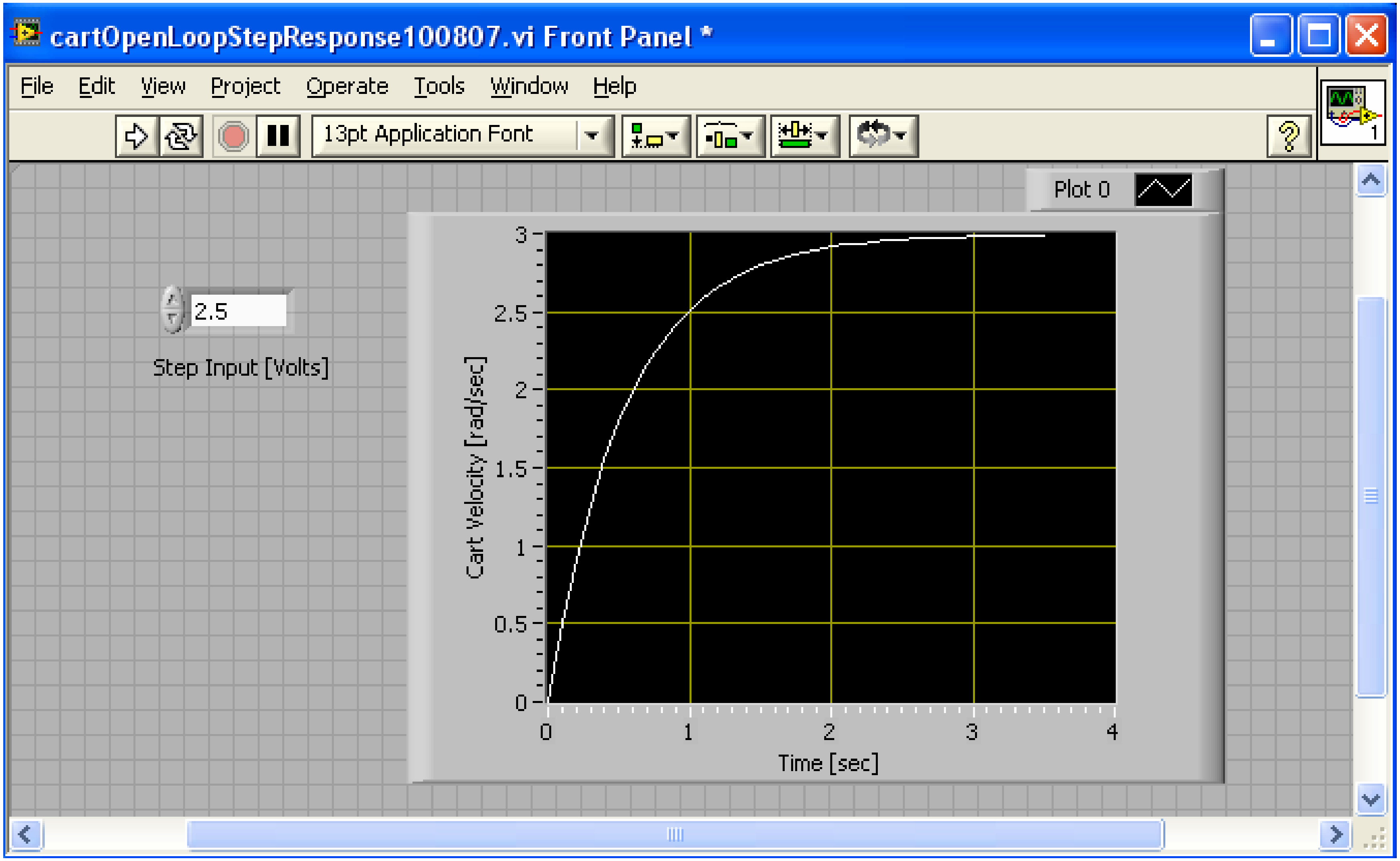
The block diagram representing (6) is simply:

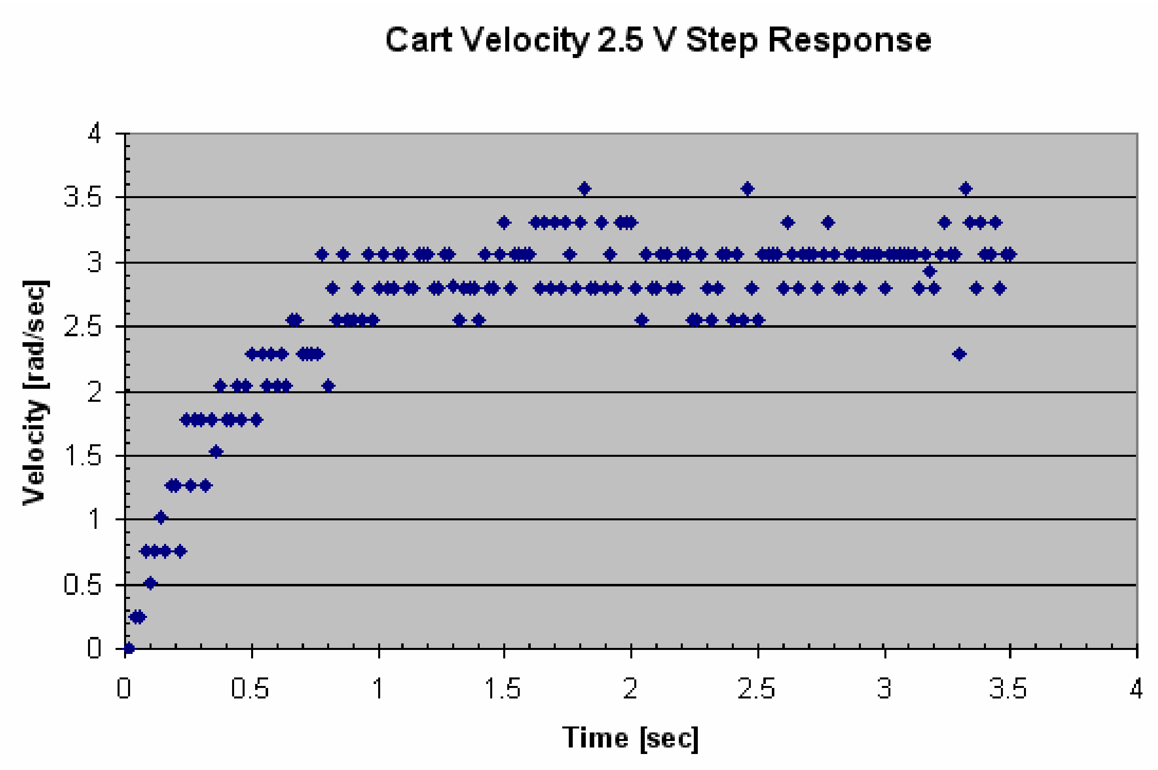


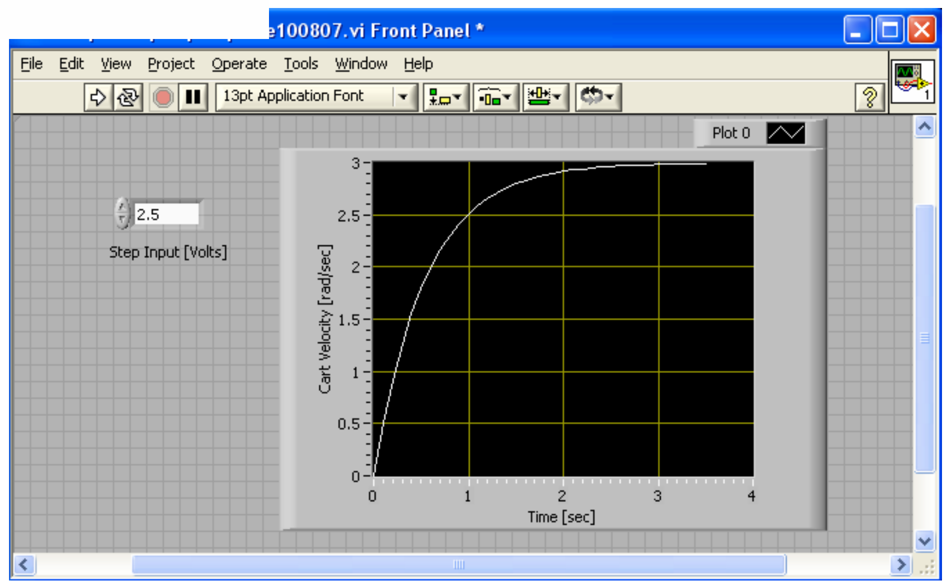
LabVIEW Block Diagram for (6)



LabVIEW Front Panel for (6)







Note: Simulation and Experimental results to step input look similar!

Lab: Open-Loop Step Response

- Apply step input voltage and capture steady-state response
- Determine steady-state gain and time constant
- Calculate open-loop transfer function
- Simulate open-loop step response
- Compare experimental and simulated step responses