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MEMO NUMBER: PPBS0001

DATE: 2-Sept-97

TO: Distribution

FROM: E. LaBudde

SUBJECT: PPBS Preliminary Math Model

ABSTRACT: This memo contains a first cut at a PPBS model. The model is expressed in the Graphical Description LanguageTM format. The Graphical files are generated by Visio V 4.1. Most of the model coefficients are gain terms derived from standard engineering models for DC motors, fluid flow and kinematics of the ball.

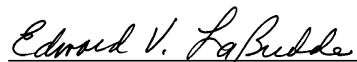
DISTRIBUTION: D. Rover, T. Bickart, PPBS modeling team

REVIEWED AND APPROVED BY:

RELATED DOCUMENTS: PPBS.VSD

ANALYSIS MODELS: None

KEY WORDS: PPBS, Fan, Fluid, Ball



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Objective

The purpose of this memo is to identify a first cut model of the PPBS for math modeling of the system.

Mission Objectives - The objective of the math model for the PPBS is to provide an executable model for CPS-479 students that can be run in the LabView environment for purposes of proving their design will work before the actual hardware is designed. The basic requirements for the model will be:

1. Accuracy - The velocity of the ball at the center of the tube shall be less than +/- 10% of full scale from the true response from any user input.
2. Time Response - The time response shall be within +/- 20% of the true response over the center 50% of the full operating range of any user input.
3. Noise - The random time variation in ball position shall be accurate to +/- 50% at the center of the tube. The User shall be able to disable the noise model by external command.
4. Interfaces - The model shall have the exact characteristics of the hardware interfaces. Cumulative response time less than 10 milliseconds can be neglected.
5. Environment - The environment shall assumed to be 70° F, and Standard Pressure for MSU Altitude. Only relevant environments need be modeled to meet the accuracy requirements.
6. Executable Model - The run time model shall require no more than 10 milliseconds of execution time when run in the LabView environment. All model parameters shall be data inputs to the model so that variations between units can be accommodated.
7. Validation Environment - A test environment shall be constructed with the ability to simultaneously command the run time model and the real hardware for validation comparisons. The test should allow pulse changes in fan voltage and valve angle and return initial values after a specified time period.

The final requirements will be confirmed after a modeling team review.

Background

The need for a math model of the PPBS arises from the “Top Down” design method being used in this term in CPS-479. It requires that students must “prove” their design approach works before they build the hardware and software. The best way to achieve this is to model the function and behavior of the overall system. One way to achieve this is to do a “simulation” of the system. The primary thrust of the model (no pun intended) is to simulate the response of the ball position from user inputs.

Glossary of Terms Used

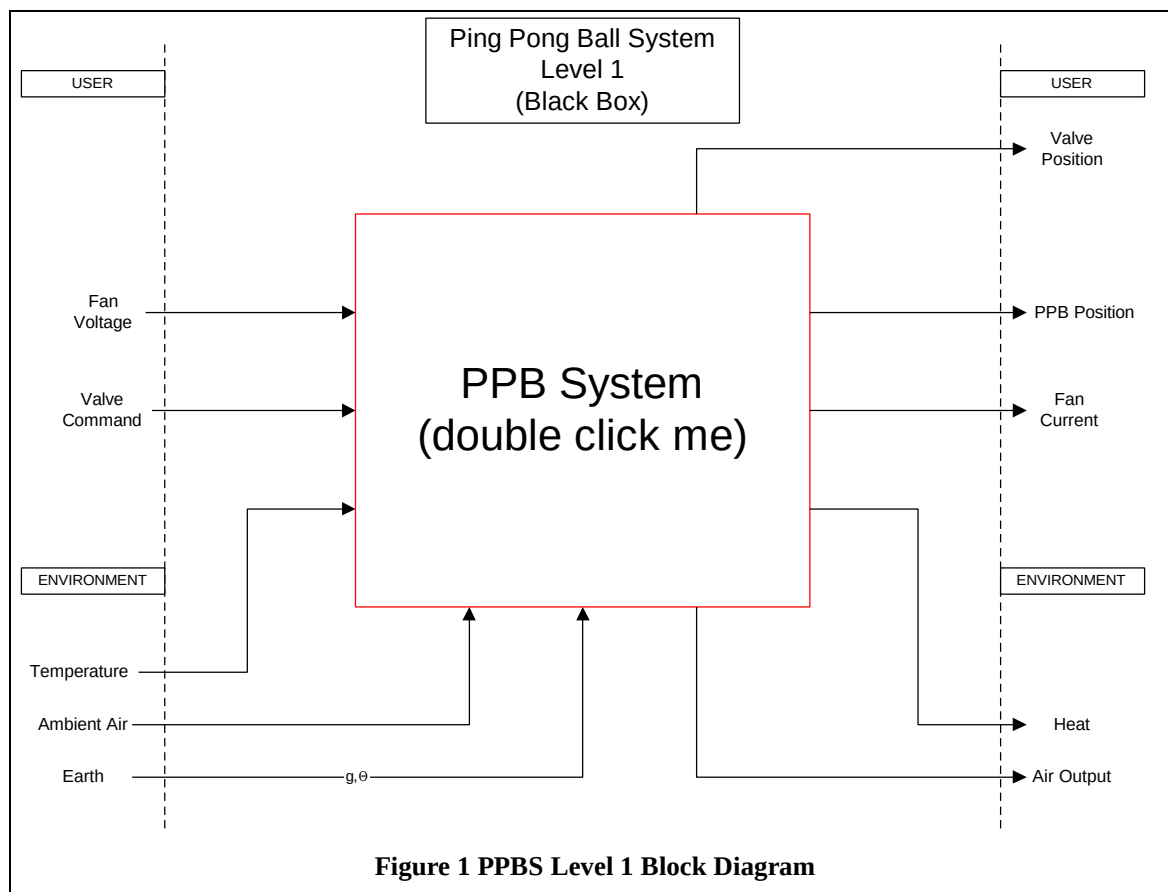
Symbol	Definition	Units	Value
Ab	Area of ball	m ²	
Ap	Area of pipe	m ²	

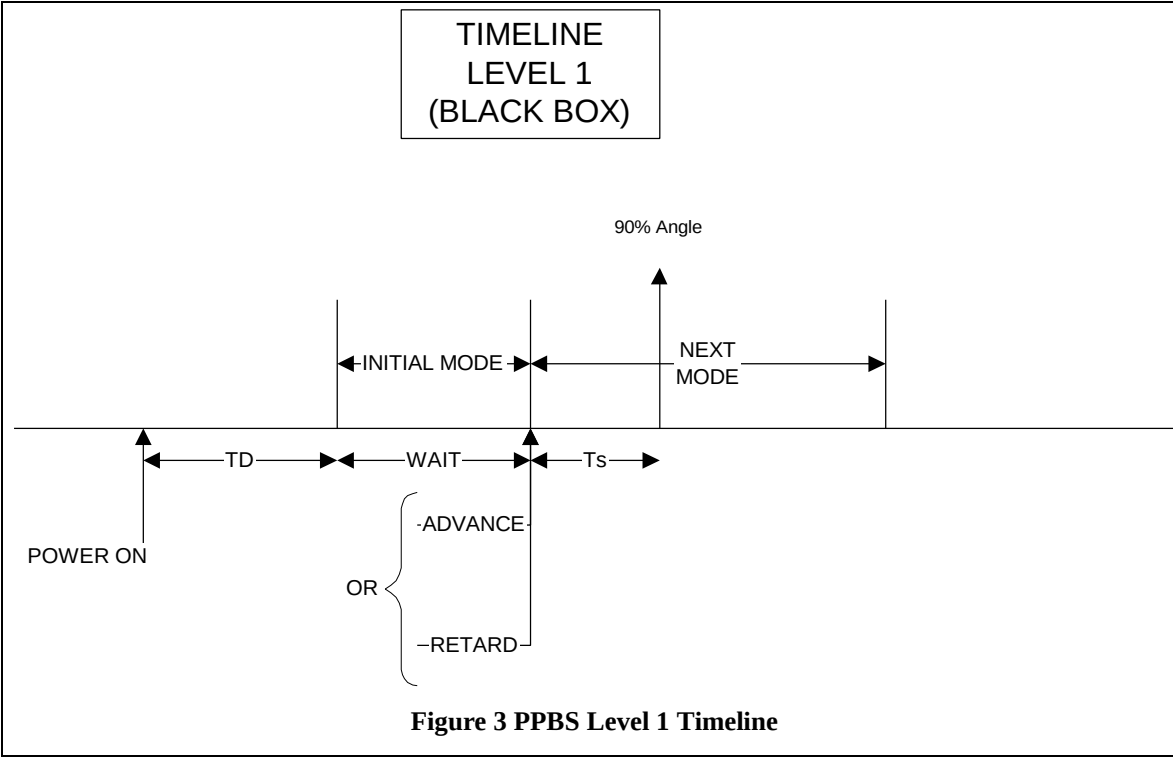
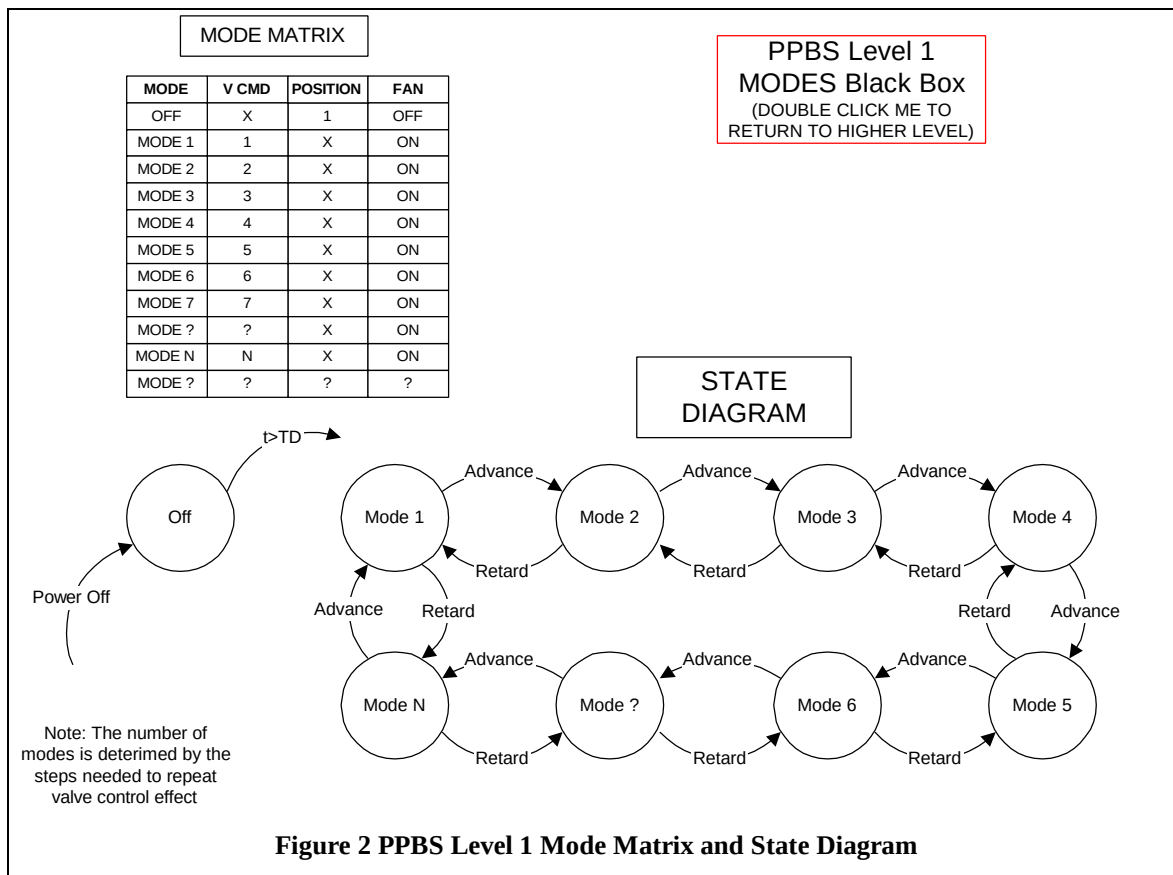
α	Acceleration of fan motor	rad/sec ²	
Cd	Ball drag coefficient	-	
Db	Diameter of Ball	m	
Dp	Diameter of Pipe	m	
F	Force on the ball due to air flow	N	
Fe	Force input to ball mass	N	
Fg	Force of gravity on ball	N	
Fn	Force due to noise	N	
Fs	Force from ball at end stops	N	
Fv	Force of ball velocity on ball	N	
g	Acceleration of gravity	m/sec ³	
Im	Fan motor current	A	
Jm	Fan moment of inertia	kg-m ²	
Kq τ	Fluid flow fan torque model	N-m-sec/m ³	
Ksi	Ball spring constant inner limit	N/m	
Kso	Ball spring constant outer limit	N/m	
Kt	Fan motor torque constant	N-m/A	
Kuf	Fluid velocity ball force model	N-sec/m	
Kuu	Mean Fluid velocity ball velocity model	-	1
Kv	Fan motor back EMF constant	V-sec/rad	
Kw	Ball-pipe wall correction constant	-	
K ω p	Fan Speed Fluid pressure Model	PA-sec/rad	
Kxr	Ball displacement fluid resistance model	PA-sec/m ²	
M	Mass of ball	kg	.00252
μ	Viscosity of air at ambient temperature	kg/m-sec	
Po	Ambient Atmospheric Pressure (at 228 meters)	PA	98661
ρ o	Ambient Atmospheric Density (at 228 meters)	kg/m3	1.1755
ρ	Air Density at the ball	kg/m3	
P	Pressure at the fan output	PA	
Q	Volume flow rate in the tube	m3/sec	
Θ	Angle of pipe from earth normal	Radian	
Re	Reynolds number		
Rm	Fan motor electrical resistance	Ohm	
Rt	Total system resistance to flow	PA-sec/m	
Rs	Resistance to flow of the piping system	PA-sec/m	
Rv	Resistance to flow at the valve, PA	PA-sec/m	
Rx	Resistance to flow at the ball, PA	PA-sec/m	
T	Ambient air temperature	°K	294
Td	Valve motor initialization time delay	Sec	
Ts	Valve motor step time delay to 90% of angle	Sec	
τ e	Torque input to fan inertia	N-m	
τ f	Friction torque from motor	N-m	

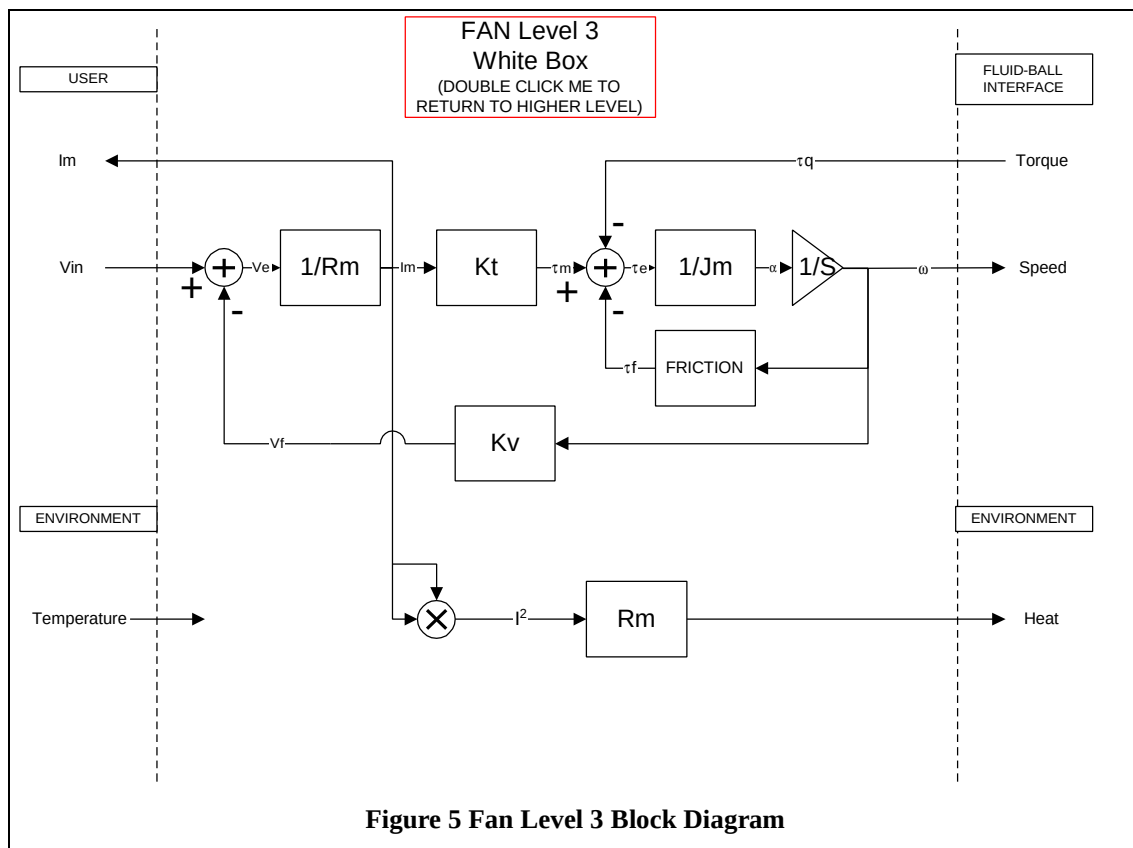
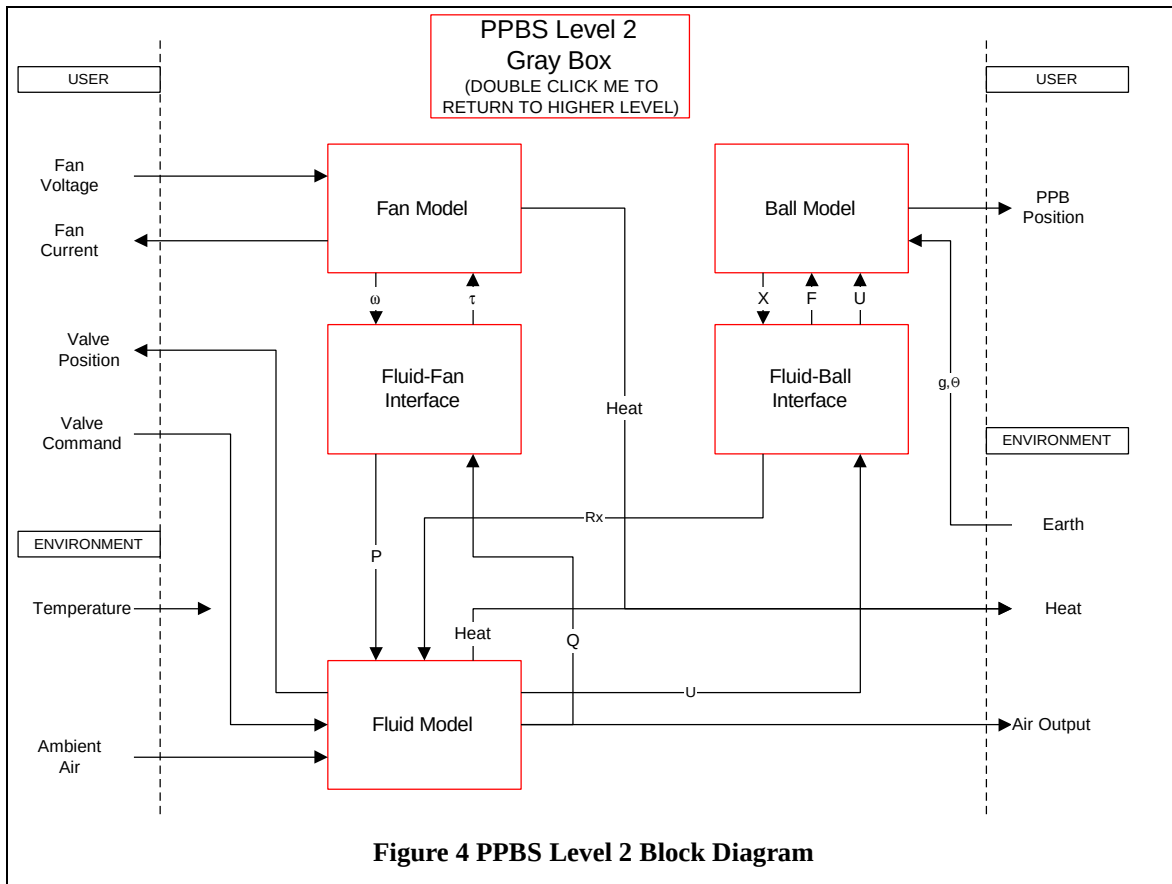
τ_m	Torque from fan motor	N-m	
τ_q	Torque from air flow	N-m	
U	Mean velocity of the fluid at the ball	m/sec	
U_i	Instantaneous Mean velocity of the fluid at the ball	m/sec	
V _{cc}	Position sensor supply voltage	V	
V _e	Voltage into fan resistance	V	
V _{in}	User voltage input to fan	V	
V _f	Back EMF from motor	V	
ω	Angular speed of fan	radian/sec	
ω_f	Corner frequency build up of flow in the pipes	radian/sec	
X	Position on ball relative to a reference surface	m	
X'	Velocity of ball relative	m/s	
X''	Acceleration of ball	m/s	

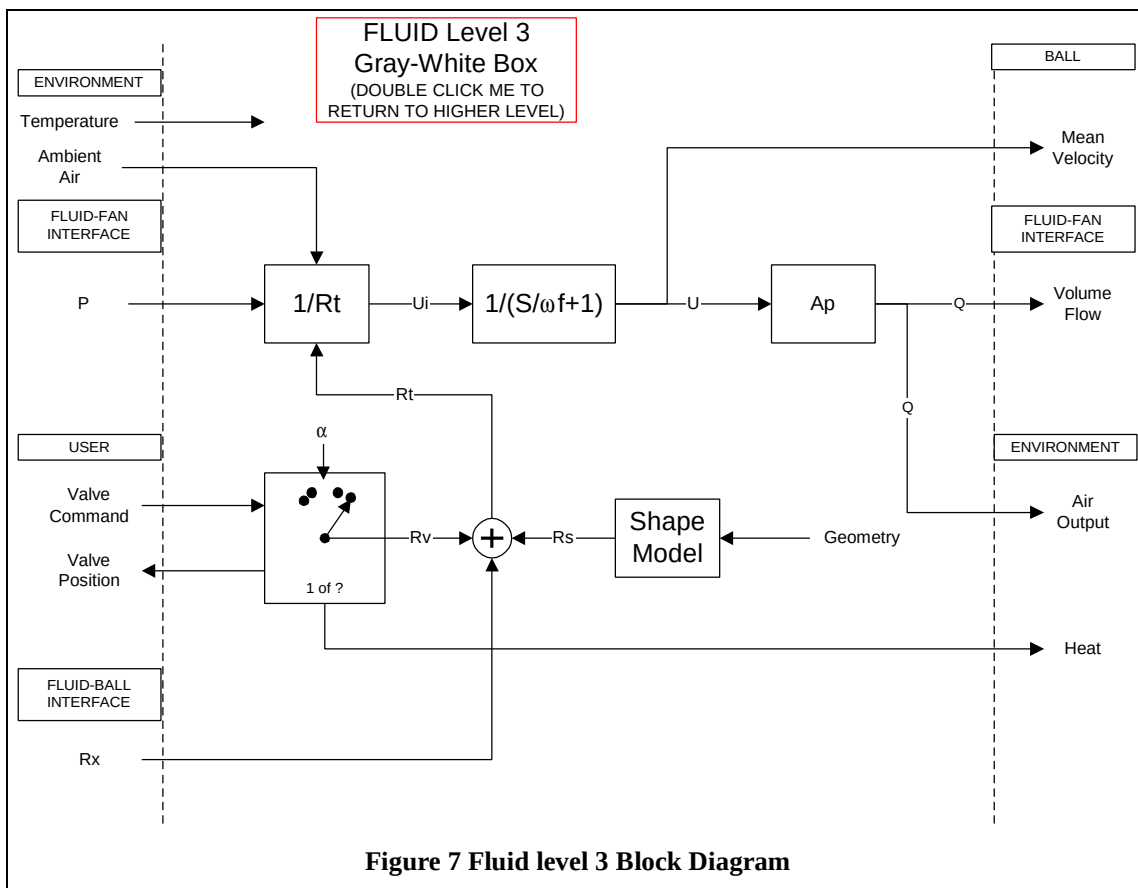
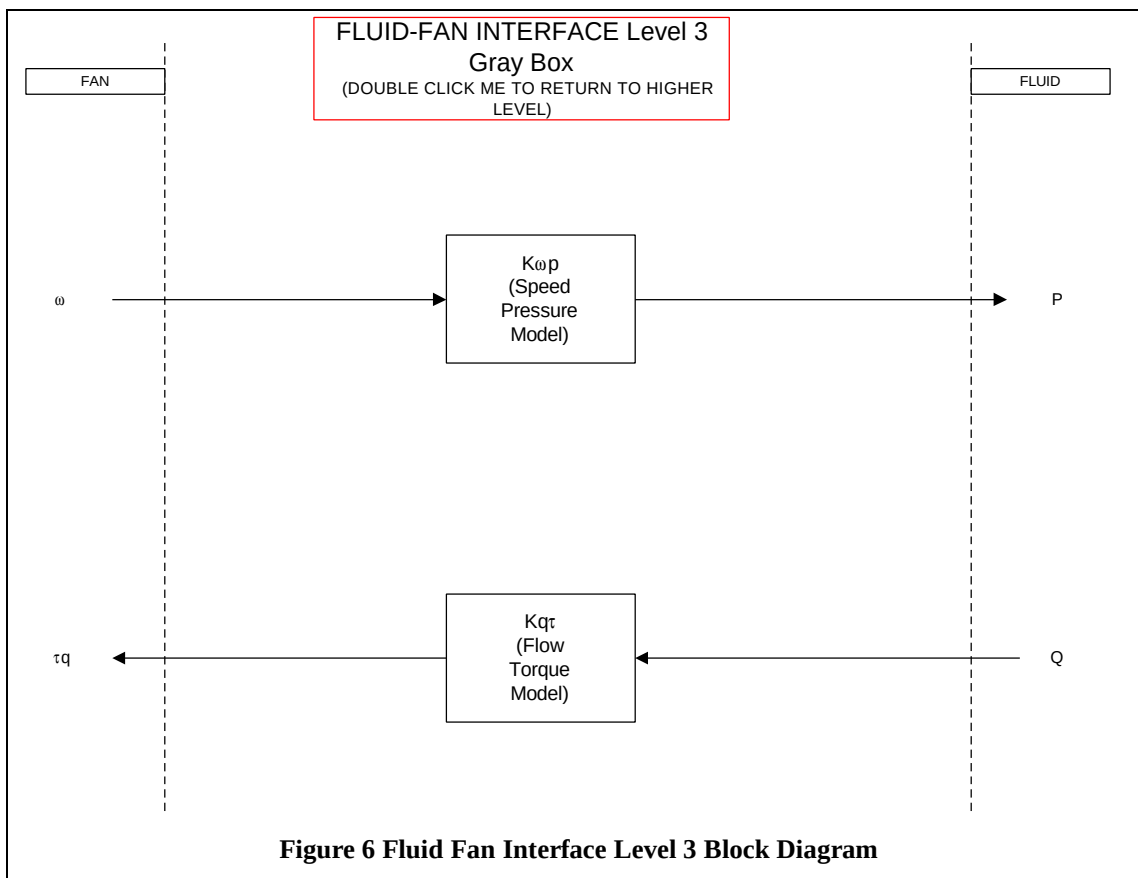
This glossary will be put into an excel spreadsheet and updated as required.

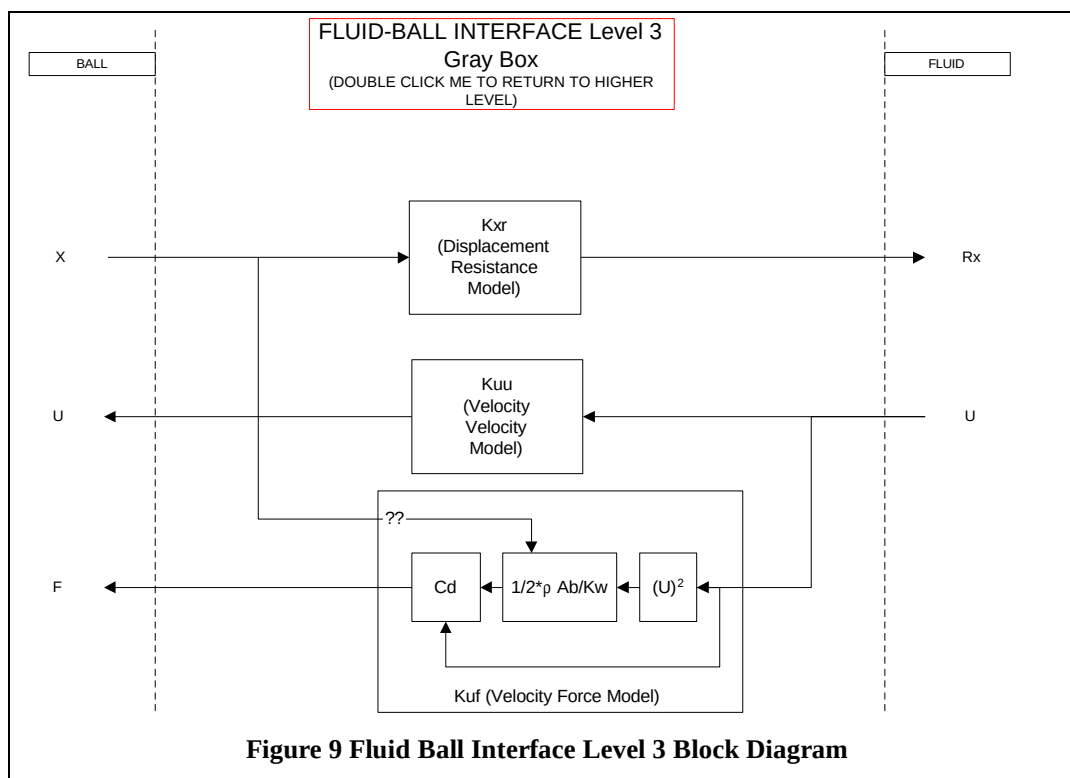
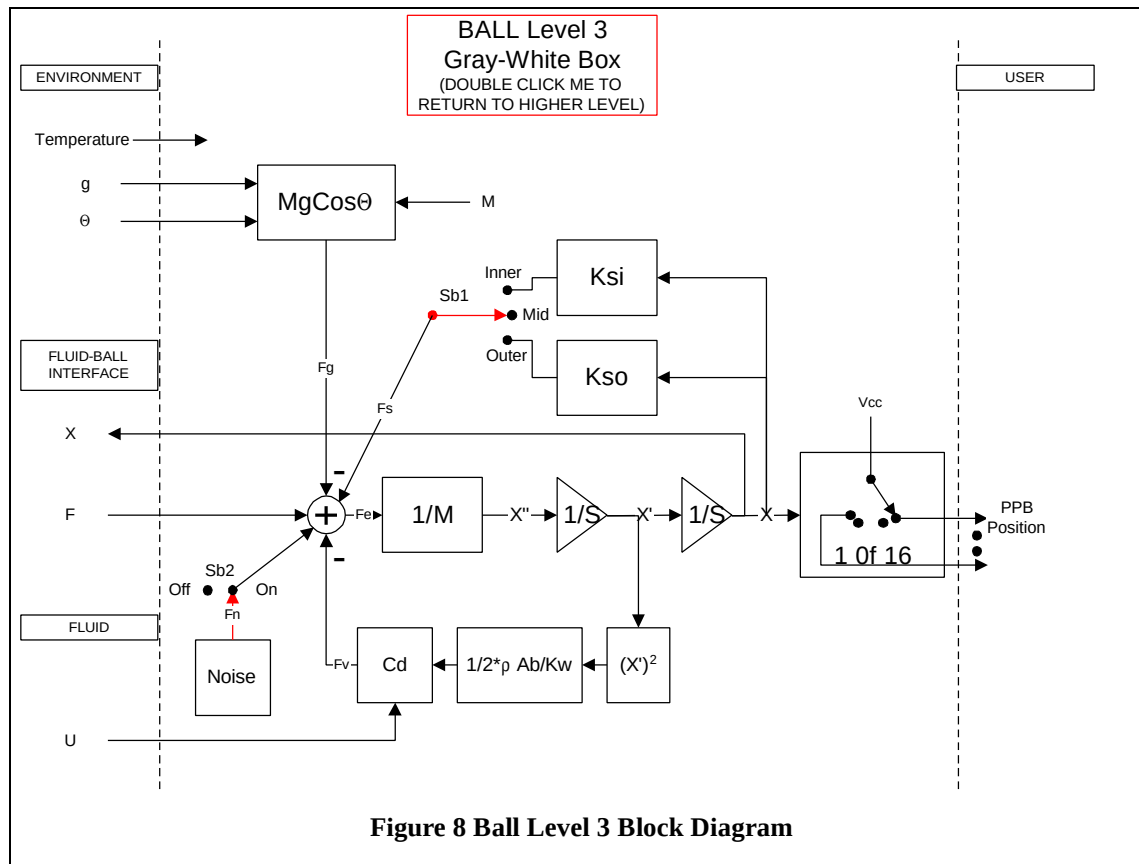
Level 1 PPBS System

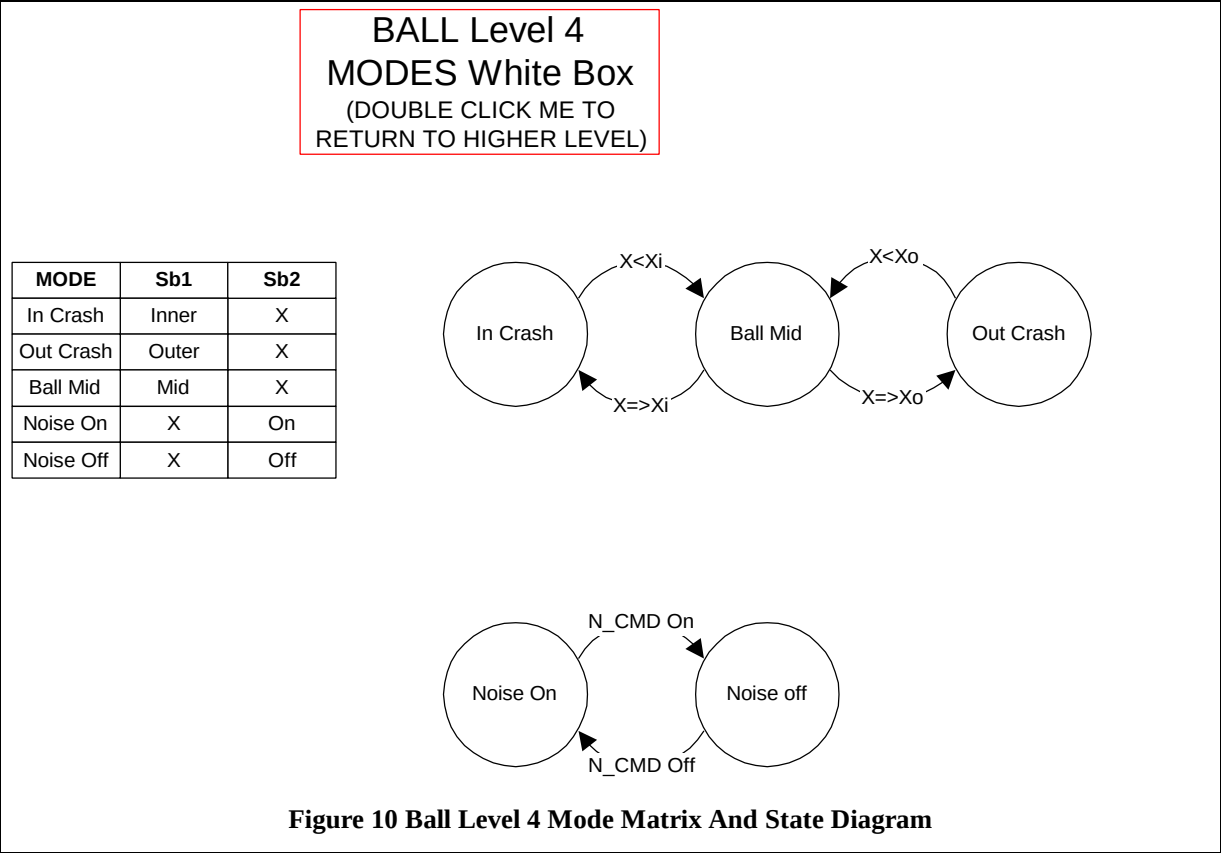












The Figures above are linked to a Visio file PPBS.VSD. Pages can be accesses by double clicking the red objects in the drawing.

The model will be developed using the MKS system of units. Raw test data can use any convent units.

Future memos will document verification test plans and model validation and run time model construction.