ARGONNE NATIONAL LABORATORY
TRANSPORTATION
TECHNOLOGY R&D CENTER

Feasibility of Reusable Vehicle Modeling: Application to Hybrid Vehicles

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SAE 2004

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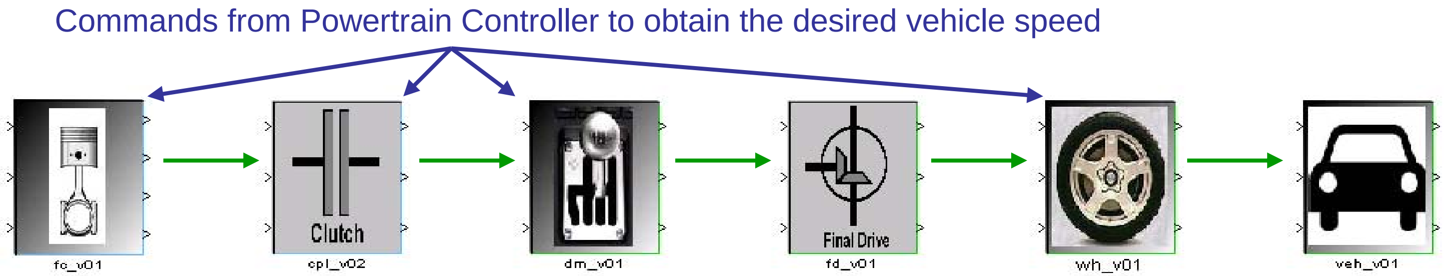
Issues Related to Vehicle Modeling

- Large number of configurations
- Models complexity selection
- Models maintenance
- Models compatibility
- Results post-processing

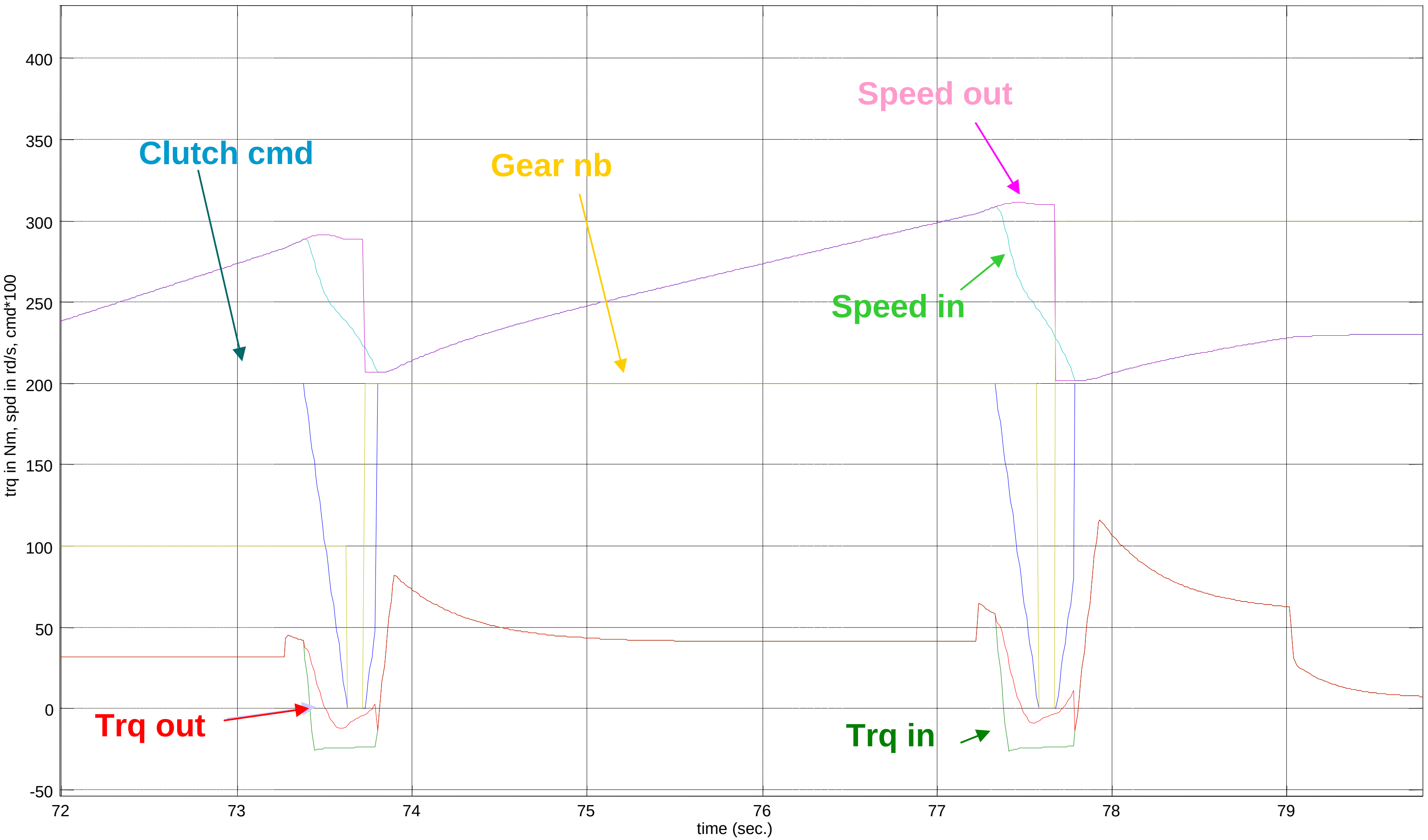
➡ Leverage resources

Control-Based Modeling

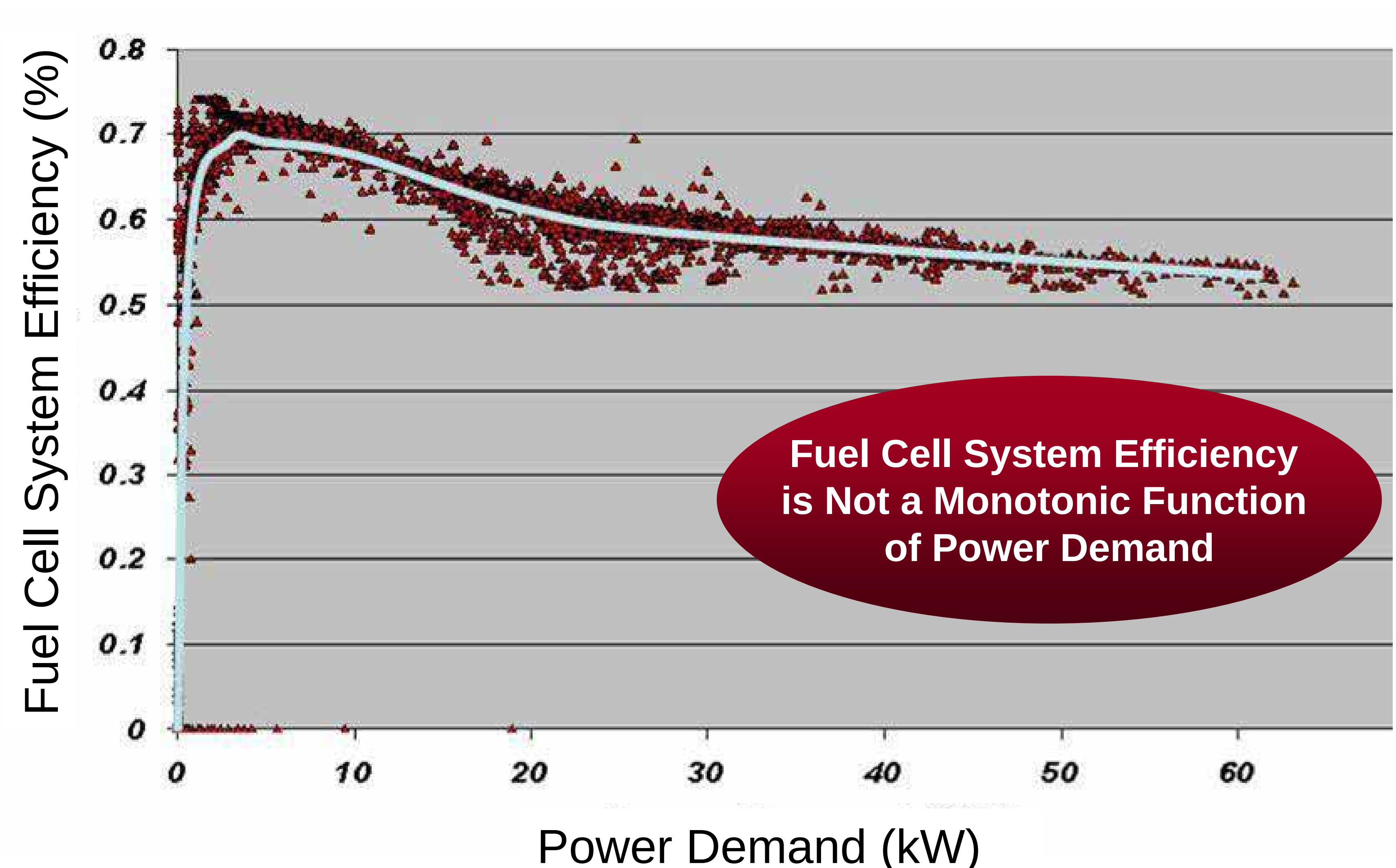
- ‘Forward’ modeling (driver-to-wheels with control and feedback) to portray transient component behavior and vehicle response
  - Component dynamics (e.g., engine starting and warm-up, shifting, clutch engagement ...)
  - Physiological component models possible
  - Control strategies that can be utilized in HIL, RCP or vehicle testing
  - Can utilize variable time steps to enhance accuracy



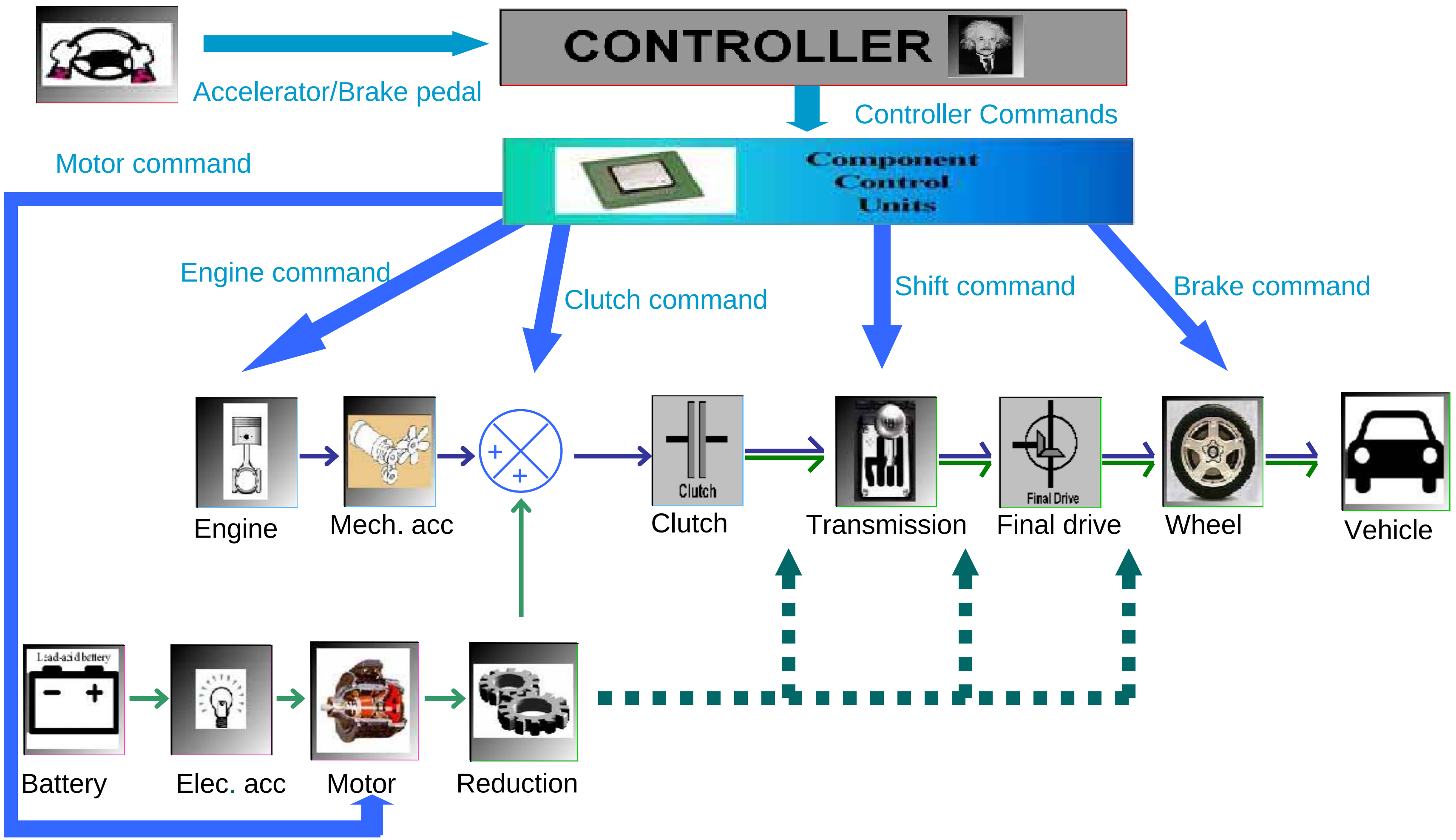
Realistic Shifting Event (0.6 sec shift with manual gearbox)

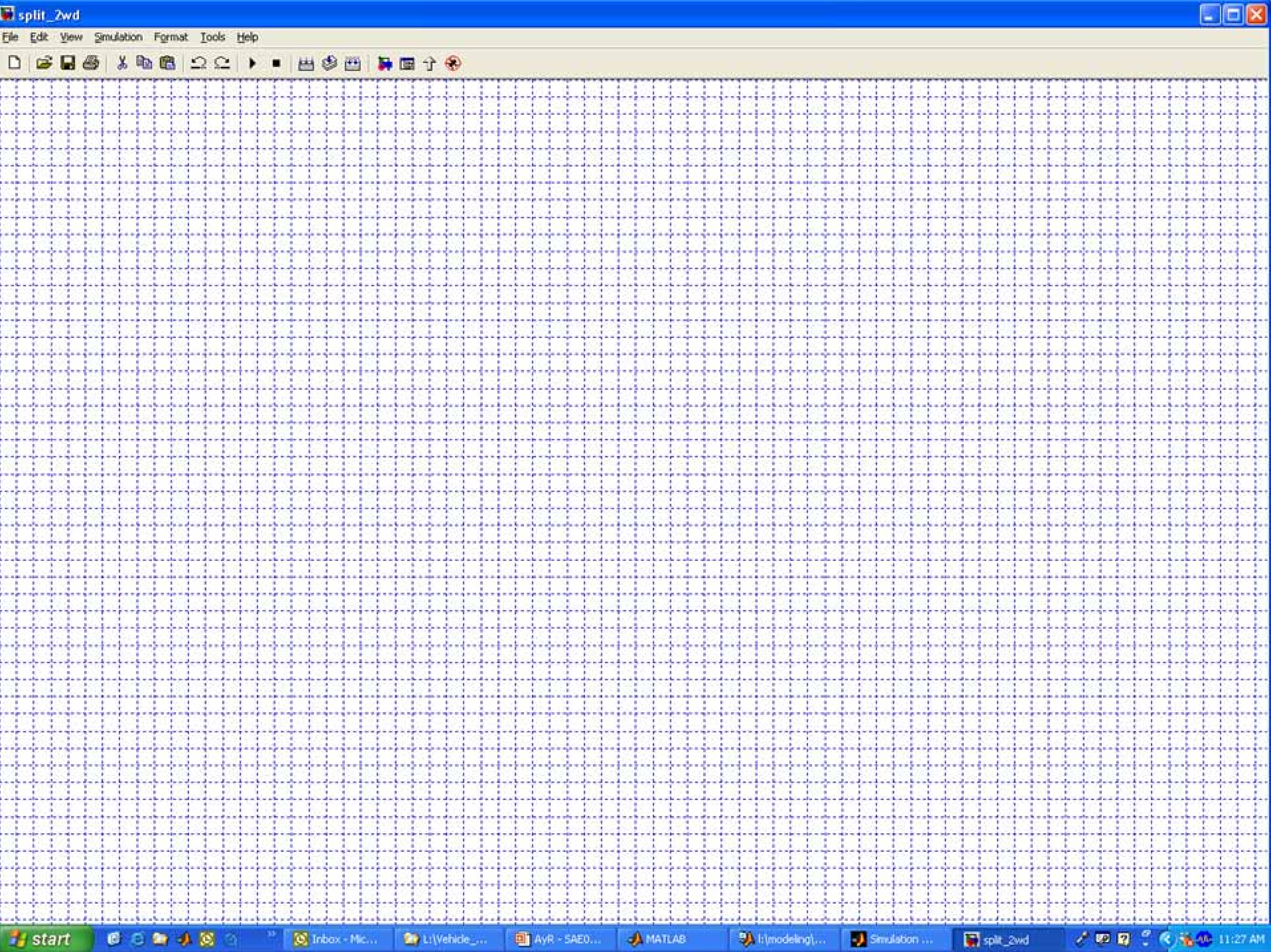


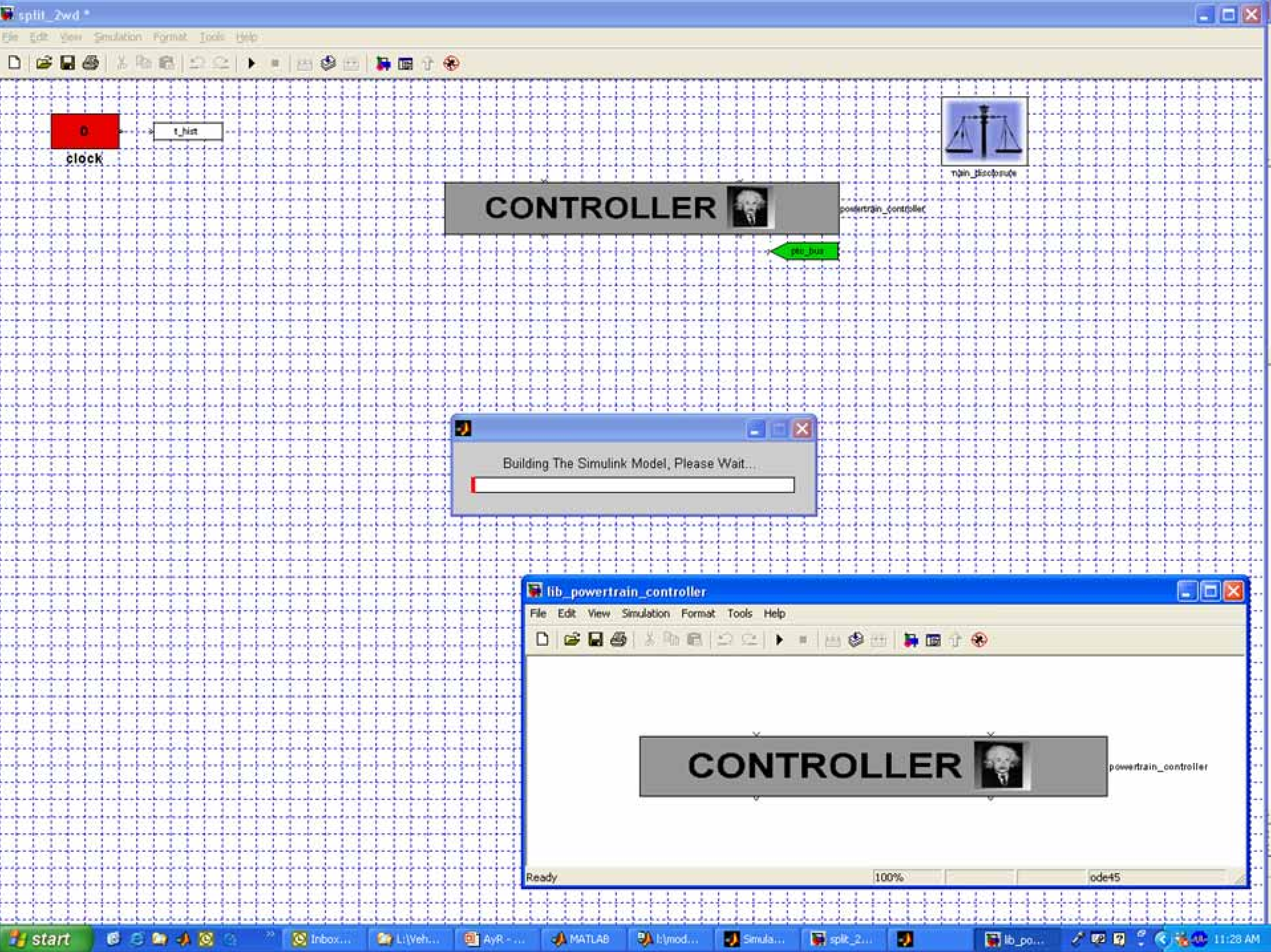
Detailed Models Necessary for Realistic Behavior

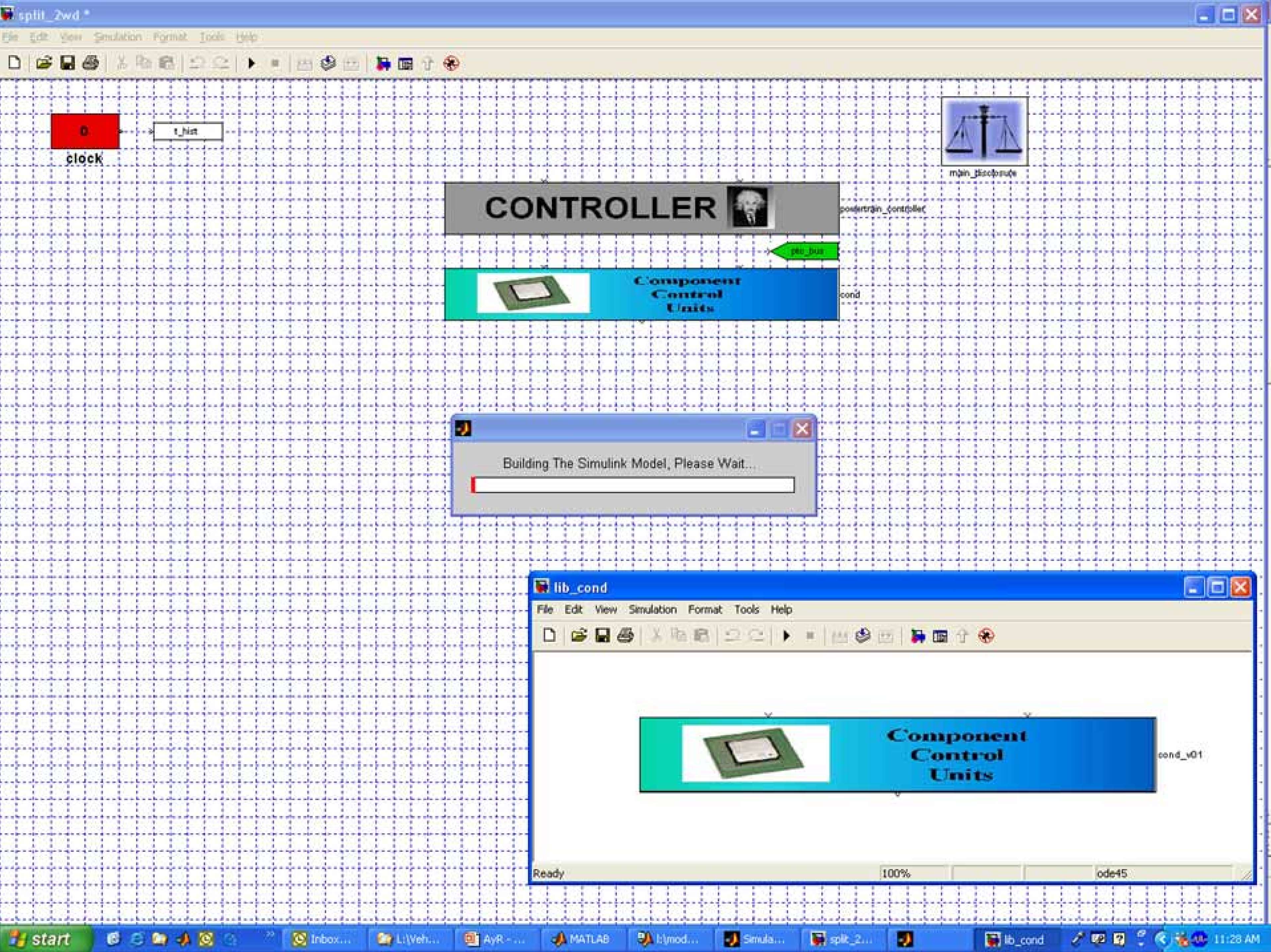


Large Number of Configurations Achieved Through Building




split_2wd
File Edit View Simulation Format Tools Help
start
Inbox - Mic...
L:\Vehicle_...
AyR - SAE0...
MATLAB
I:\modeling\...
Simulation ...
split_2wd
11:27 AM


split_2wd *
0
clock
t_hist
CONTROLLER
Building The Simulink Model, Please Wait...
lib_powertrain_controller
File Edit View Simulation Format Tools Help
CONTROLLER
powertrain_controller
Ready
100%
ode45
start
MATLAB
11:28 AM


split_2wd *
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0
clock
t_hist
main_disclosure
CONTROLLER
powertrain_controller
ptc_bus
Component Control Units
cond
Building The Simulink Model, Please Wait...
lib_cond
File Edit View Simulation Format Tools Help
Component Control Units
cond_v01
Ready
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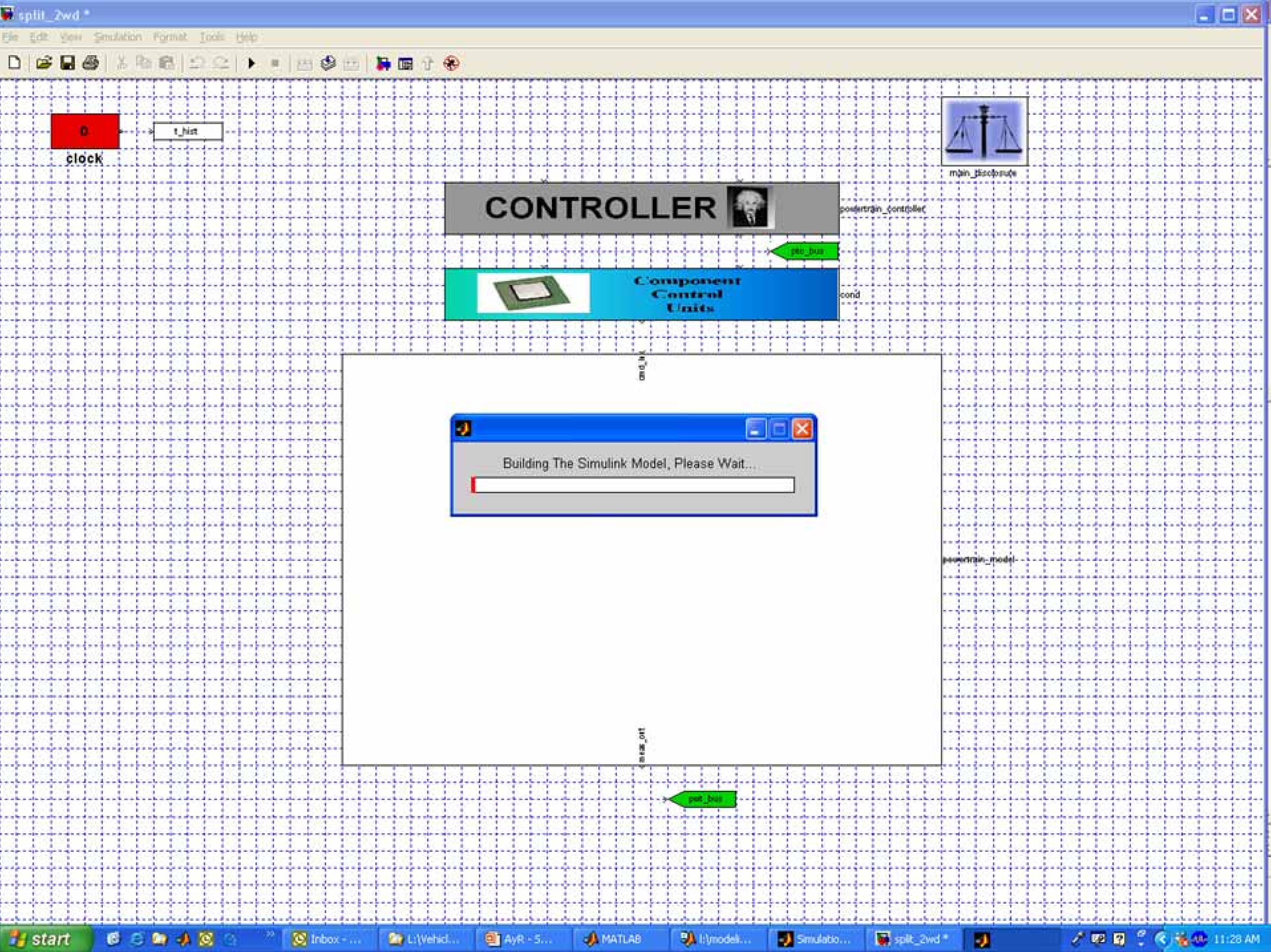
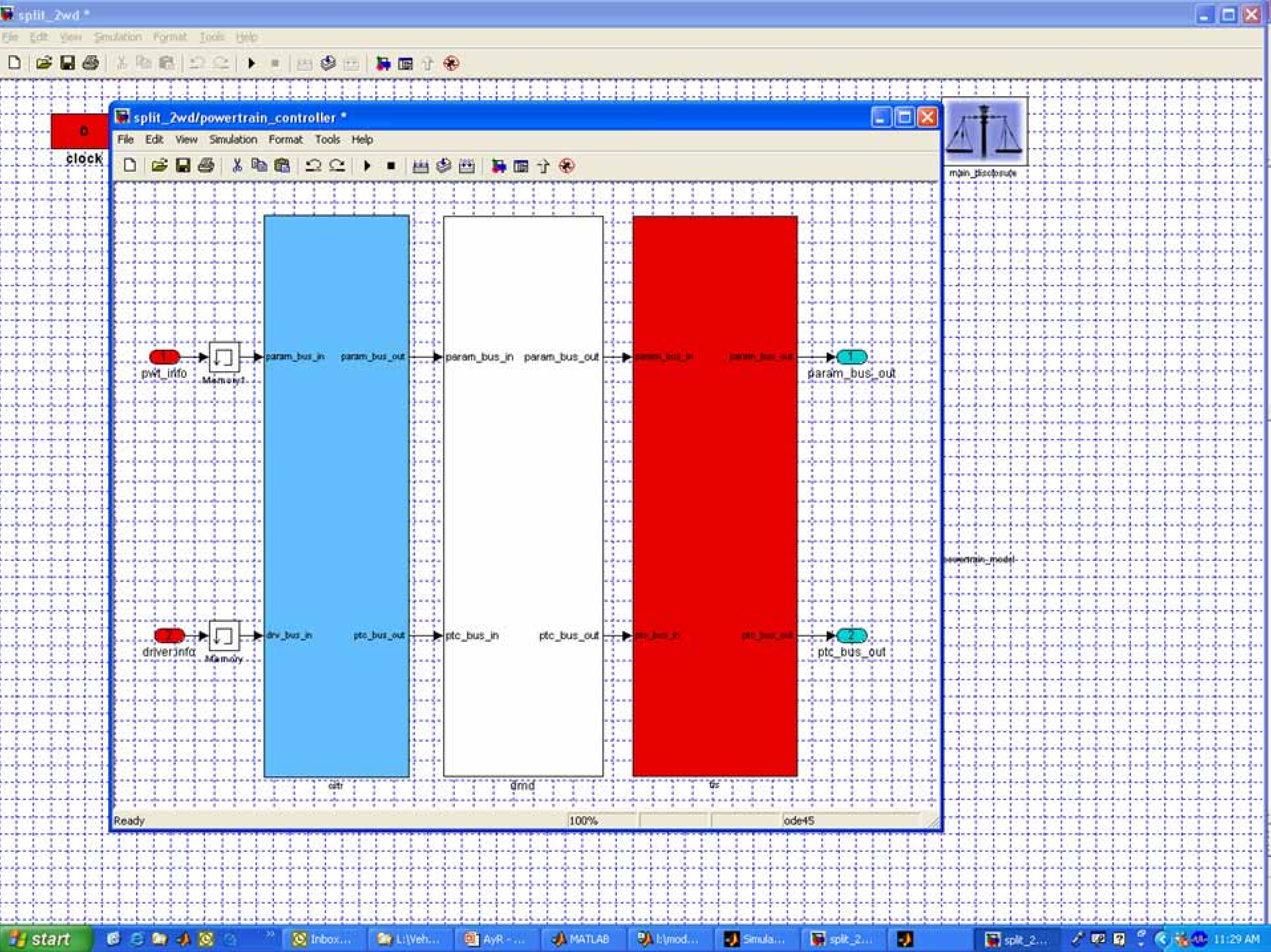
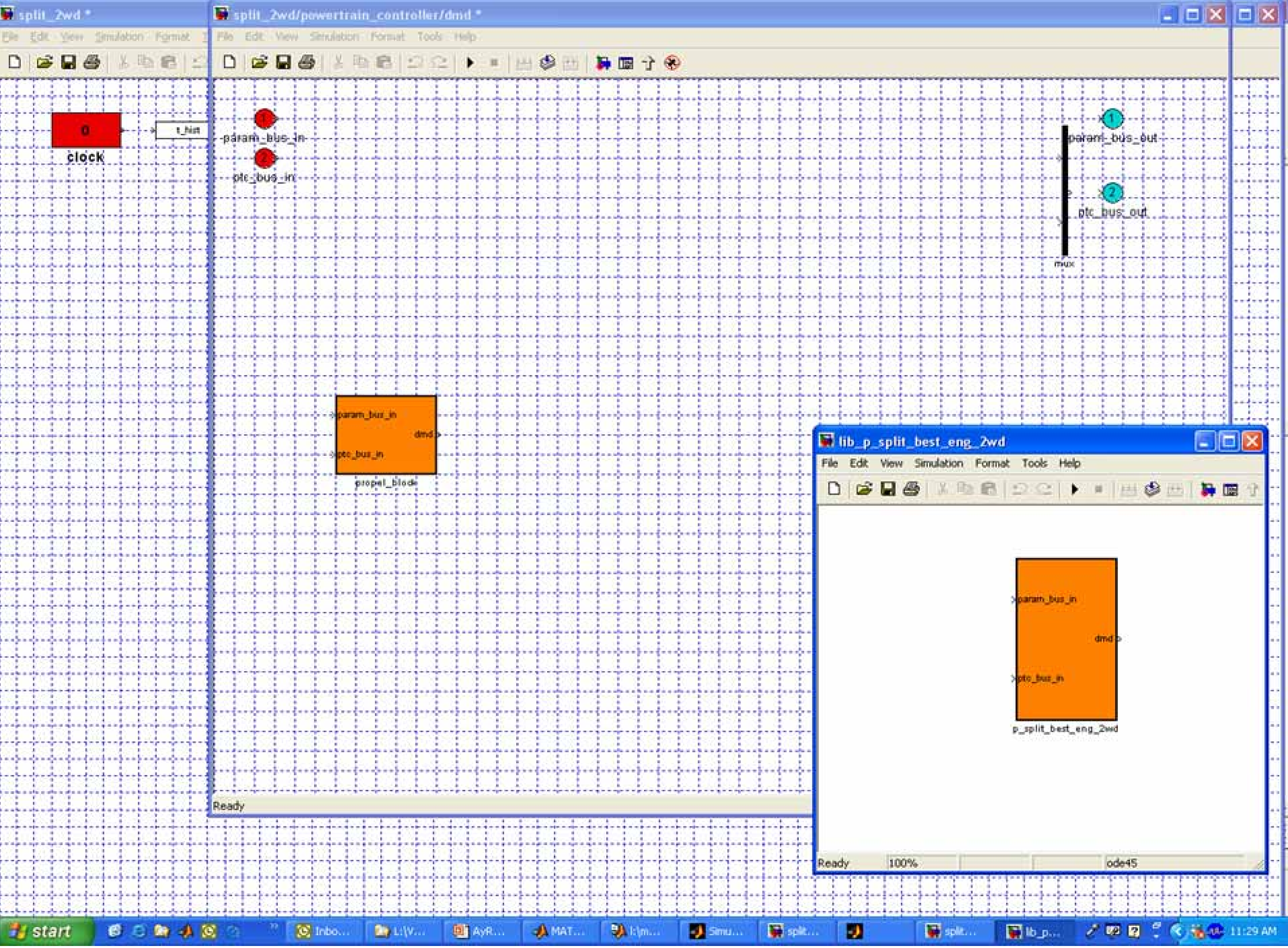
ode45
start
MATLAB
lib_cond
11:28 AM



split_2wd *
File Edit View Simulation Format Tools Help
clock
t_hist
main_disclosure
CONTROLLER
powertrain_controller
ptc_bus
Component
Control
Units
cond
Building The Simulink Model, Please Wait...
powertrain_model
pwt_bus
start
MATLAB
split_2wd *
11:28 AM


split_2wd *
File Edit View Simulation Format Tools Help
clock
split_2wd/powertrain_controller *
File Edit View Simulation Format Tools Help
pwt_info
driver info
Memory
param_bus_in
param_bus_out
drv_bus_in
ptc_bus_out
ptc_bus_in
dmd
param_bus_out
ptc_bus_out
powertrain_model
Ready
100%
ode45
start
MATLAB
11:29 AM


split_2wd *
clock
t_hist
split_2wd/powertrain_controller/dmd *
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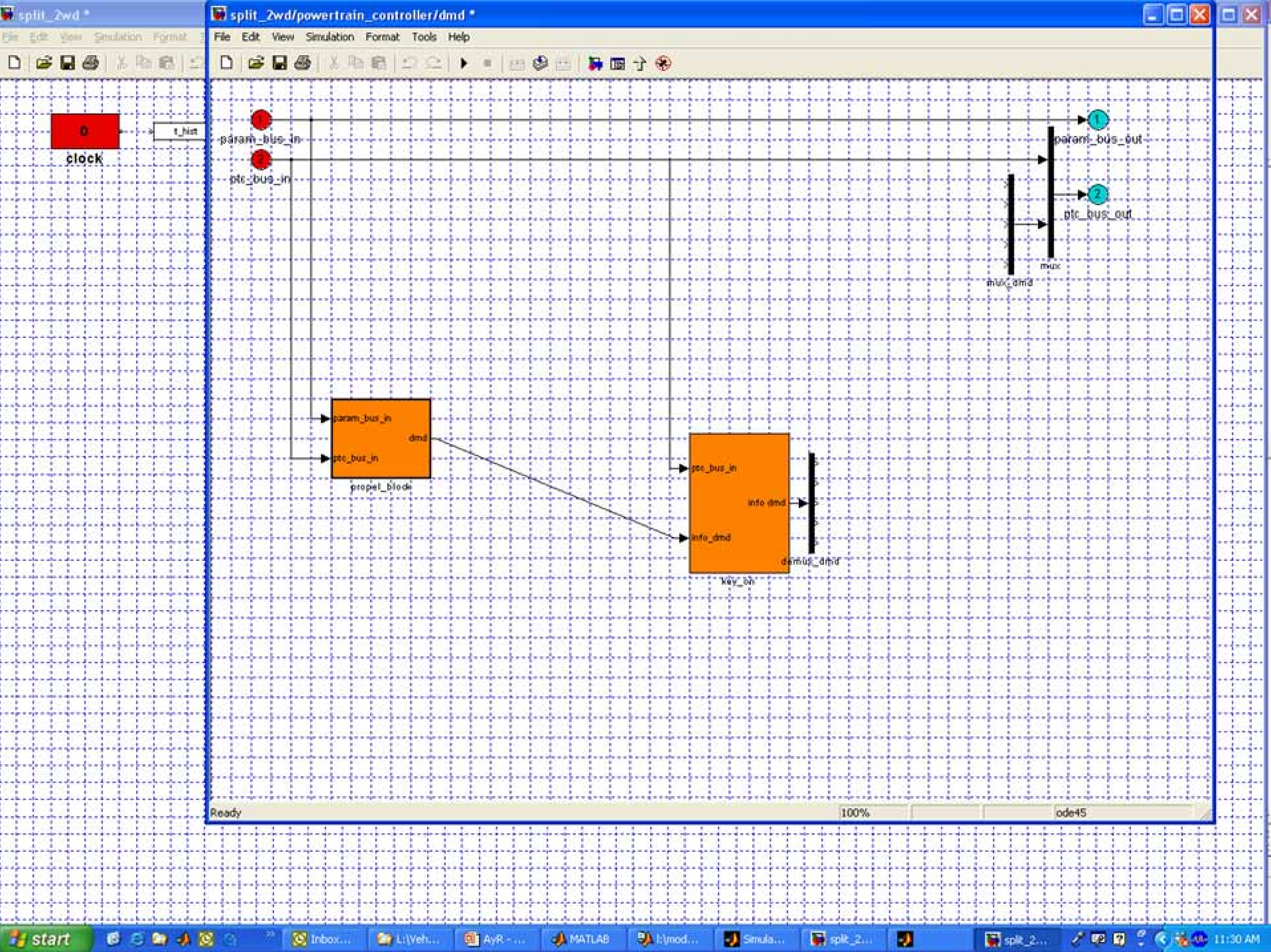
param_bus_in
ptc_bus_in
param_bus_out
ptc_bus_out
mux
param_bus_in
dmd
ptc_bus_in
propel_block
Ready
lib_p_split_best_eng_2wd
File Edit View Simulation Format Tools Help
param_bus_in
dmd
ptc_bus_in
p_split_best_eng_2wd
Ready
100%
ode45
start
11:29 AM


split_2wd *
split_2wd/powertrain_controller/dmd *
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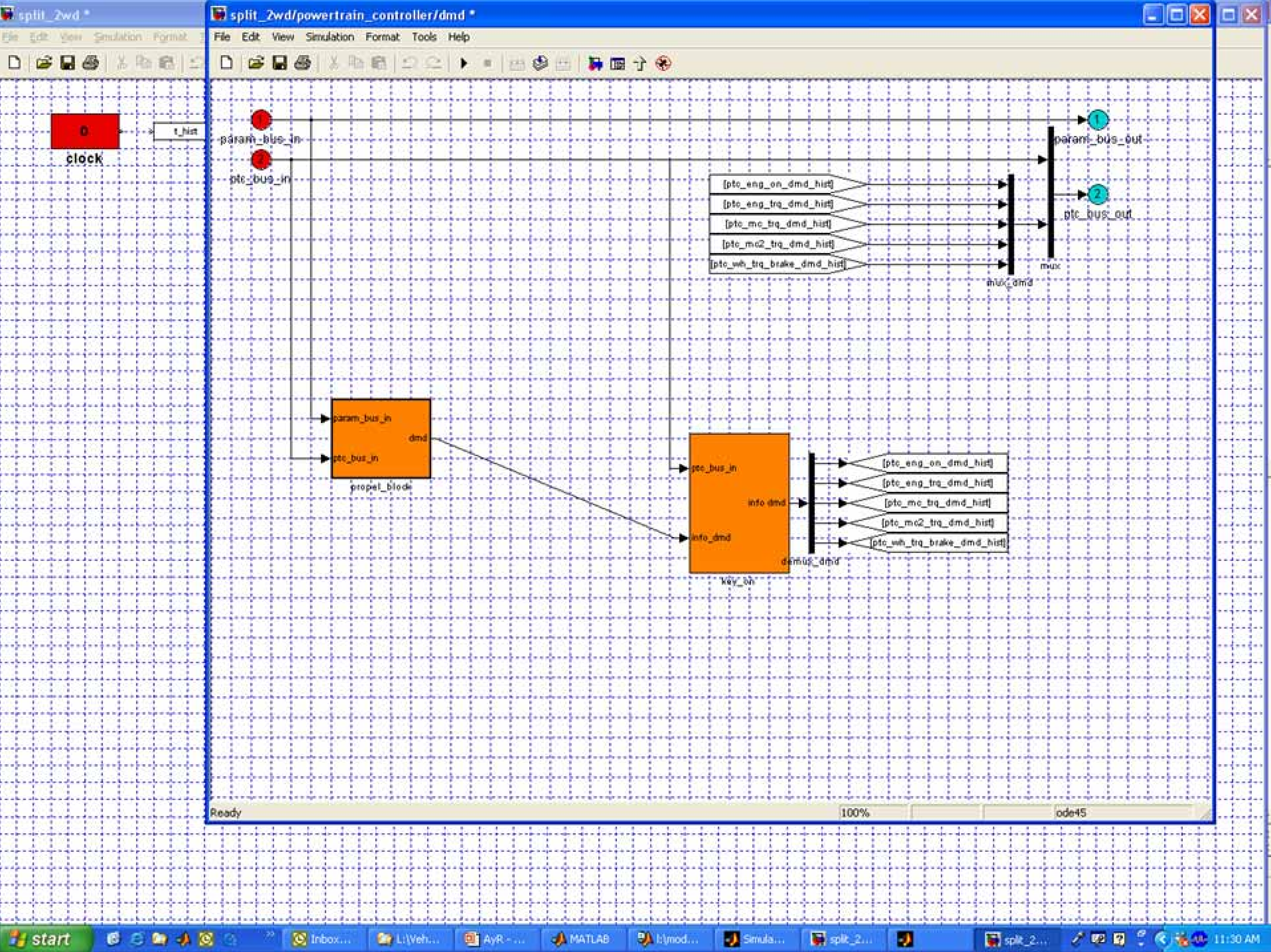
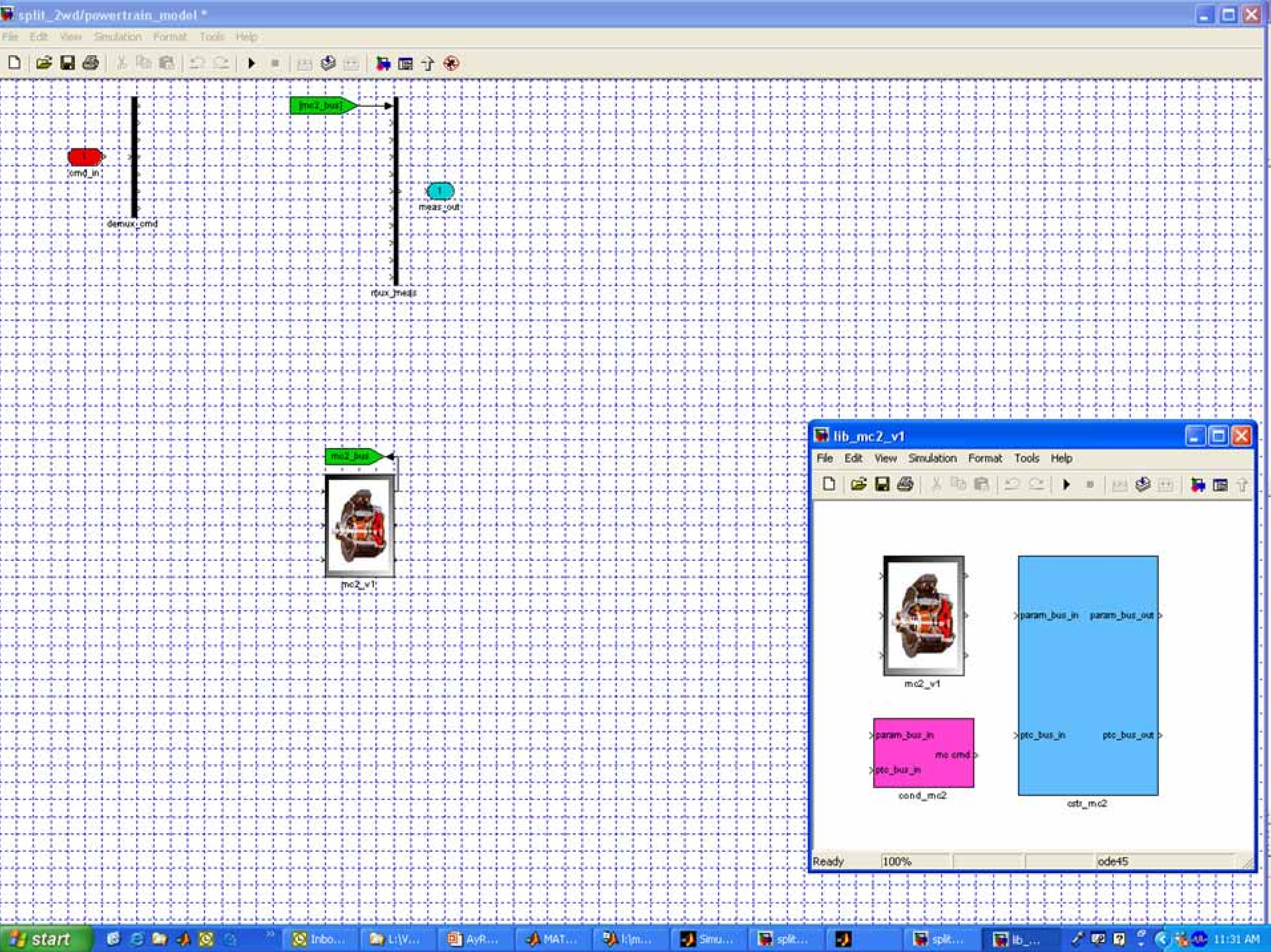
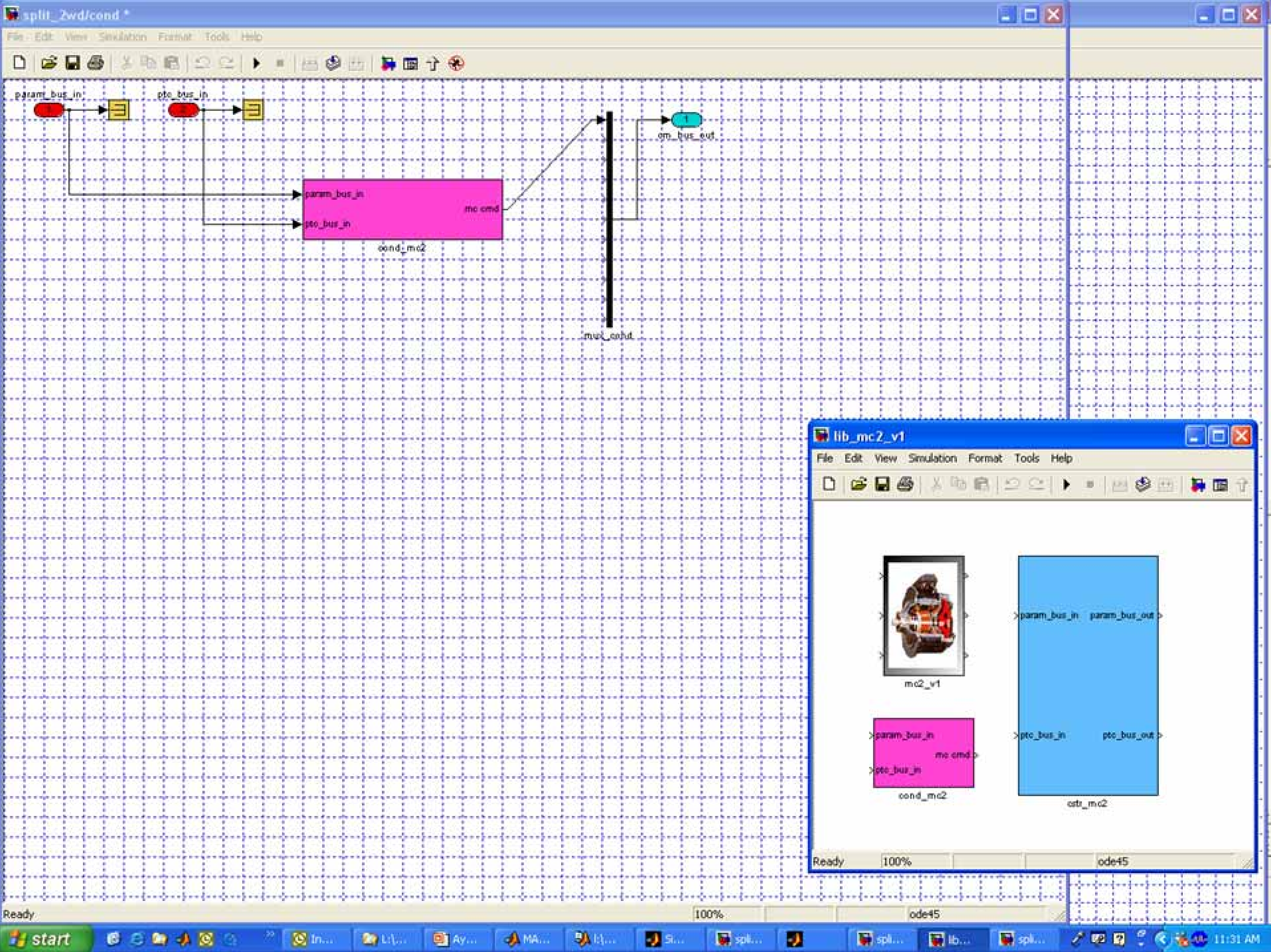
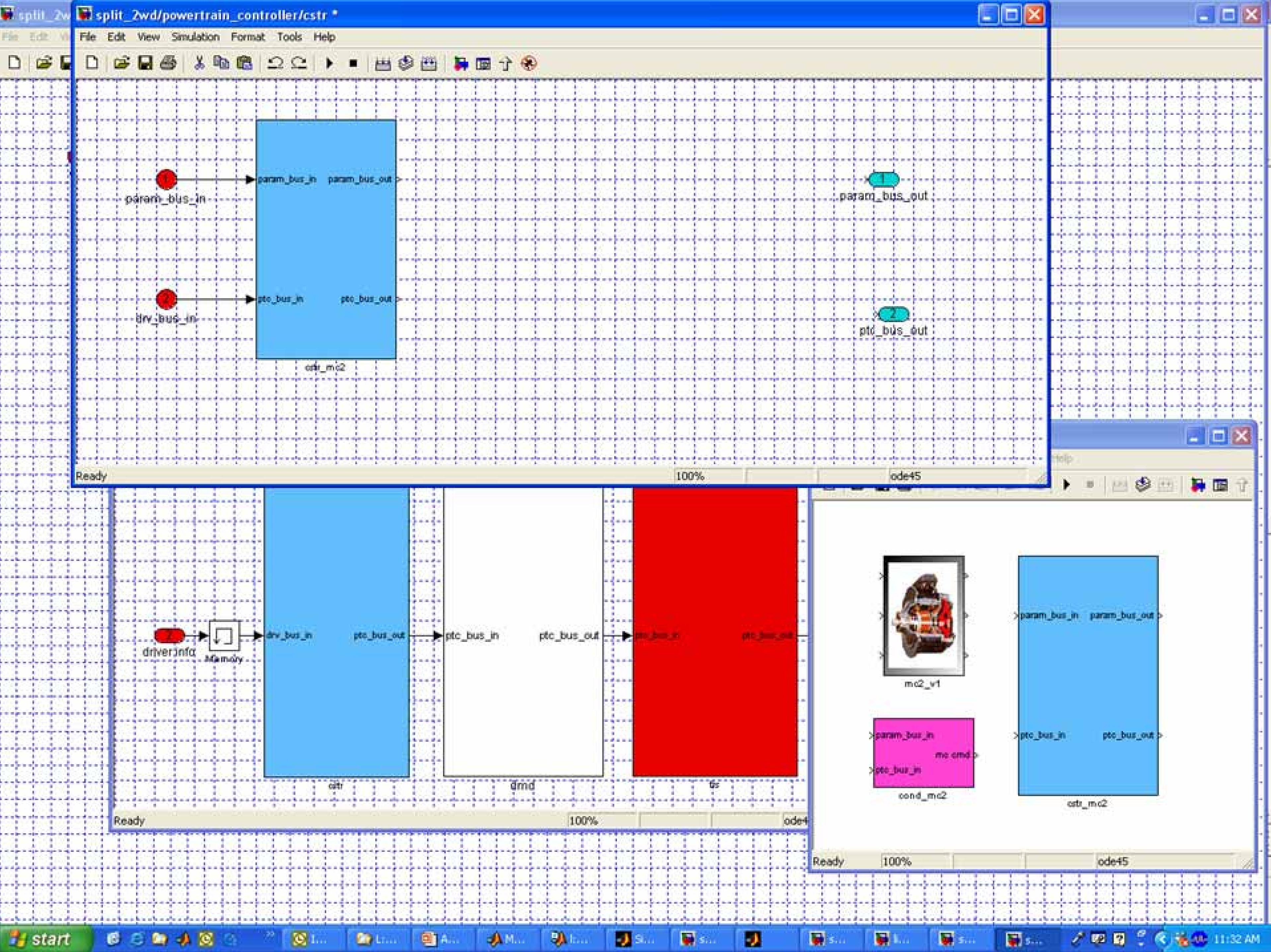
clock
t_hist
param_bus_in
ptc_bus_in
param_bus_out
ptc_bus_out
mux_dmd
mux
param_bus_in
ptc_bus_in
dmd
propel_blode
ptc_bus_in
info dmd
info_dmd
key_on
demux_dmd
Ready
100%
ode45
start
Inbox...
MATLAB
Simula...
11:30 AM


split_2wd/powertrain_controller/dmd *
File Edit View Simulation Format Tools Help
clock
t_hist
param_bus_in
ptc_bus_in
param_bus_out
ptc_bus_out
[ptc_eng_on_dmd_hist]
[ptc_eng_trq_dmd_hist]
[ptc_mc_trq_dmd_hist]
[ptc_mc2_trq_dmd_hist]
[ptc_wh_trq_brake_dmd_hist]
mux_dmd
mux
dmd
propel_blode
info_dmd
key_on
demux_dmd
Ready
100%
ode45
start
11:30 AM


split_2wd/powertrain_model *
File Edit View Simulation Format Tools Help
[mc2_bus]
cmd_in
demux_cmd
meas_out
mux_meas
mc2_bus
mc2_v1
lib_mc2_v1
File Edit View Simulation Format Tools Help
mc2_v1
param_bus_in
param_bus_out
ptc_bus_in
ptc_bus_out
param_bus_in
mc cmd
ptc_bus_in
cond_mc2
Ready
100%
ode45
start
11:31 AM


split_2wd/cond *
File Edit View Simulation Format Tools Help
param_bus_in
pto_bus_in
param_bus_in
pto_bus_in
mc cmd
cond_mc2
mux_cond
cm_bus_out
Ready
100%
ode45
lib_mc2_v1
File Edit View Simulation Format Tools Help
mc2_v1
param_bus_in
pto_bus_in
mc cmd
cond_mc2
param_bus_in
param_bus_out
pto_bus_in
pto_bus_out
Ready
100%
ode45
start
11:31 AM


split_2wd/powertrain_controller/cstr *
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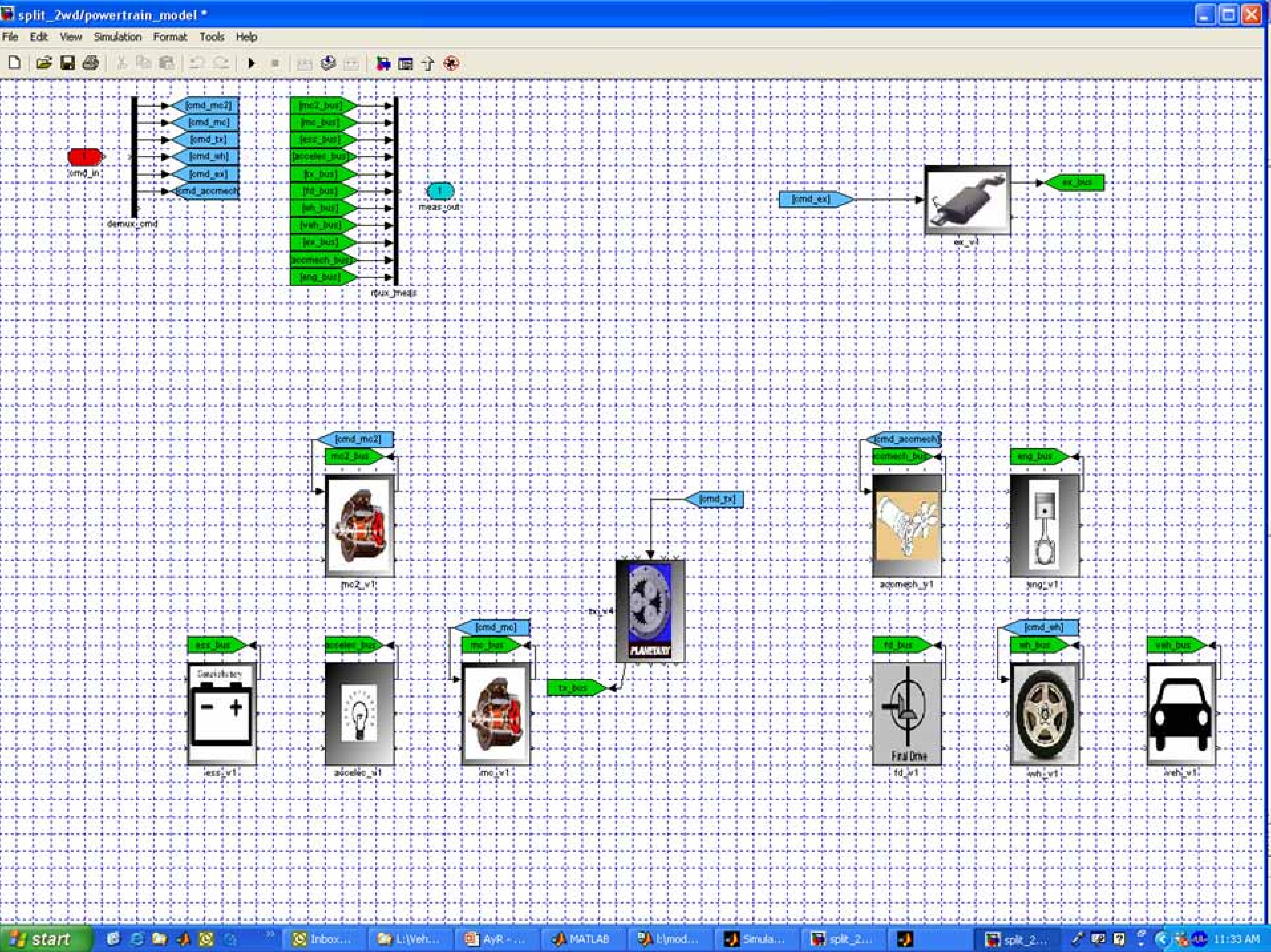
param_bus_in
param_bus_out
ptc_bus_in
ptc_bus_out
drv_bus_in
cstr_mc2
Ready
100%
ode45
driver.info
Memory
cstr
dmd
cond_mc2
mc2_v1
mc cmd
start
11:32 AM


split_2wd/powertrain_model *
File Edit View Simulation Format Tools Help
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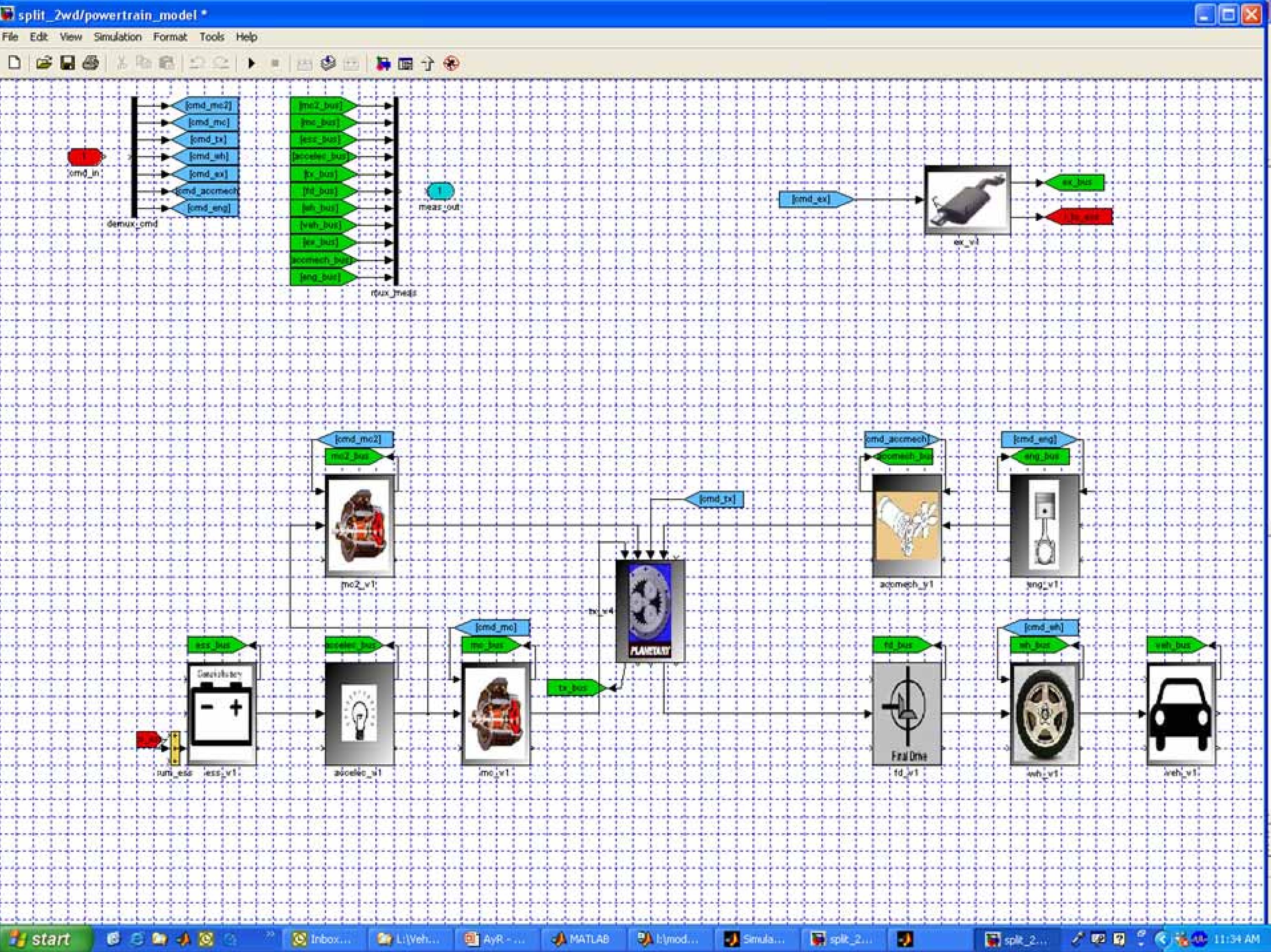
[cmd_mc]
[cmd_tx]
[cmd_wh]
[cmd_ex]
[cmd_acomech]
cmd_in
demux_cmd
[mc2_bus]
[mc_bus]
[ess_bus]
[accelec_bus]
[tx_bus]
[fd_bus]
[wh_bus]
[veh_bus]
[ex_bus]
[acomech_bus]
[eng_bus]
mux_meas
meas_out
ex_bus
ex_v1
mc2_bus
mc2_v1
tx_v4
acomech_v1
eng_bus
eng_v1
ess_bus
ess_v1
accelec_bus
accelec_v1
mc_bus
mc_v1
tx_bus
fd_bus
Final Drive
fd_v1
wh_bus
wh_v1
veh_bus
veh_v1
start
MATLAB
11:33 AM


split_2wd/powertrain_model *
File Edit View Simulation Format Tools Help
[cmd_mc2]
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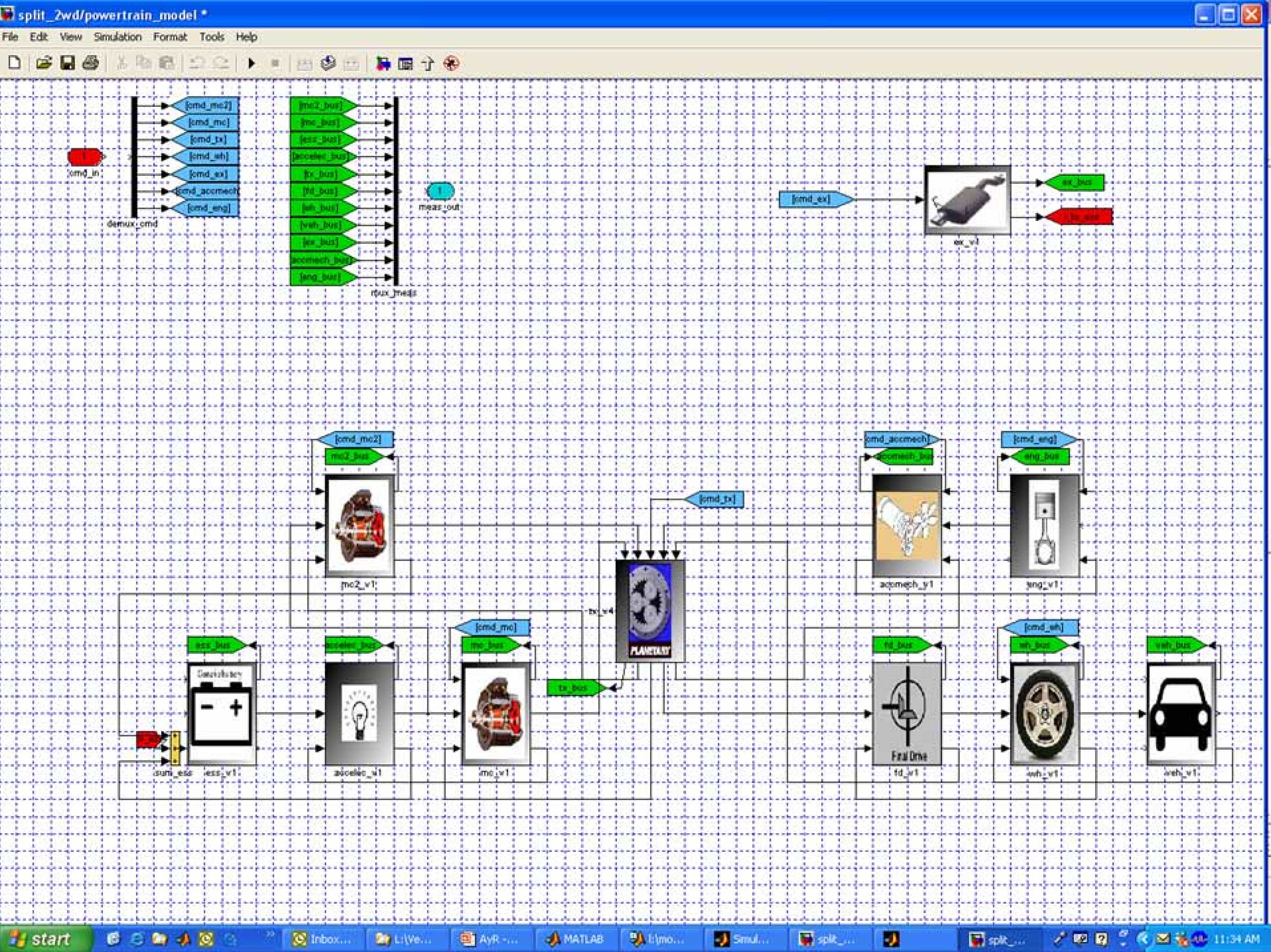
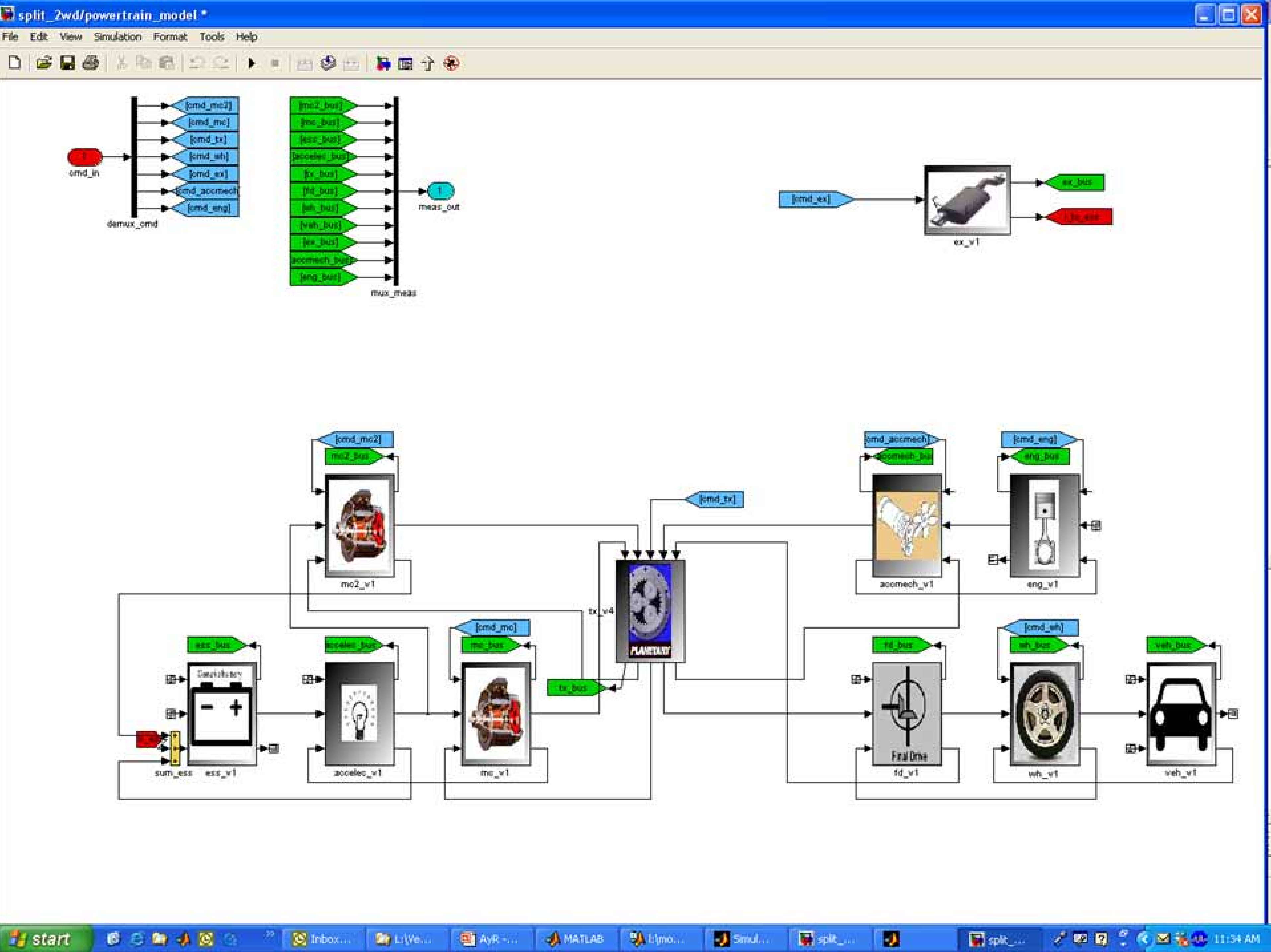
mux_meas
meas_out
ex_v1
mc2_v1
tx_v4
accmech_v1
eng_v1
ess_v1
accelec_v1
mc_v1
fd_v1
wh_v1
veh_v1
Final Drive
start
MATLAB
11:34 AM


split_2wd/powertrain_model *
File Edit View Simulation Format Tools Help
[cmd_mc2]
[cmd_mc]
[cmd_tx]
[cmd_wh]
[cmd_ex]
[cmd_accmech]
[cmd_eng]
cmd_in
demux_cmd
[mc2_bus]
[mc_bus]
[ess_bus]
[accelec_bus]
[tx_bus]
[fd_bus]
[wh_bus]
[veh_bus]
[ex_bus]
[accmech_bus]
[eng_bus]
mux_meas
meas_out
ex_bus
ex_v1
mc2_bus
mc2_v1
accmech_bus
accmech_v1
eng_bus
eng_v1
tx_v4
PLANETARY
tx_bus
ess_bus
ess_v1
sum_ess
accelec_bus
accelec_v1
mc_bus
mc_v1
fd_bus
Final Drive
fd_v1
wh_bus
wh_v1
veh_bus
veh_v1
start
MATLAB
11:34 AM


split_2wd/powertrain_model *
File Edit View Simulation Format Tools Help
[cmd_mc2]
[cmd_mc]
[cmd_tx]
[cmd_wh]
[cmd_ex]
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[cmd_eng]
cmd_in
demux_cmd
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[accelec_bus]
[tx_bus]
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[wh_bus]
[veh_bus]
[ex_bus]
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[eng_bus]
meas_out
mux_meas
ex_bus
ex_v1
mc2_bus
mc2_v1
accmech_bus
eng_bus
accmech_v1
eng_v1
tx_v4
PLANETARY
ess_bus
accelec_bus
mc_bus
tx_bus
fd_bus
wh_bus
veh_bus
sum_ess
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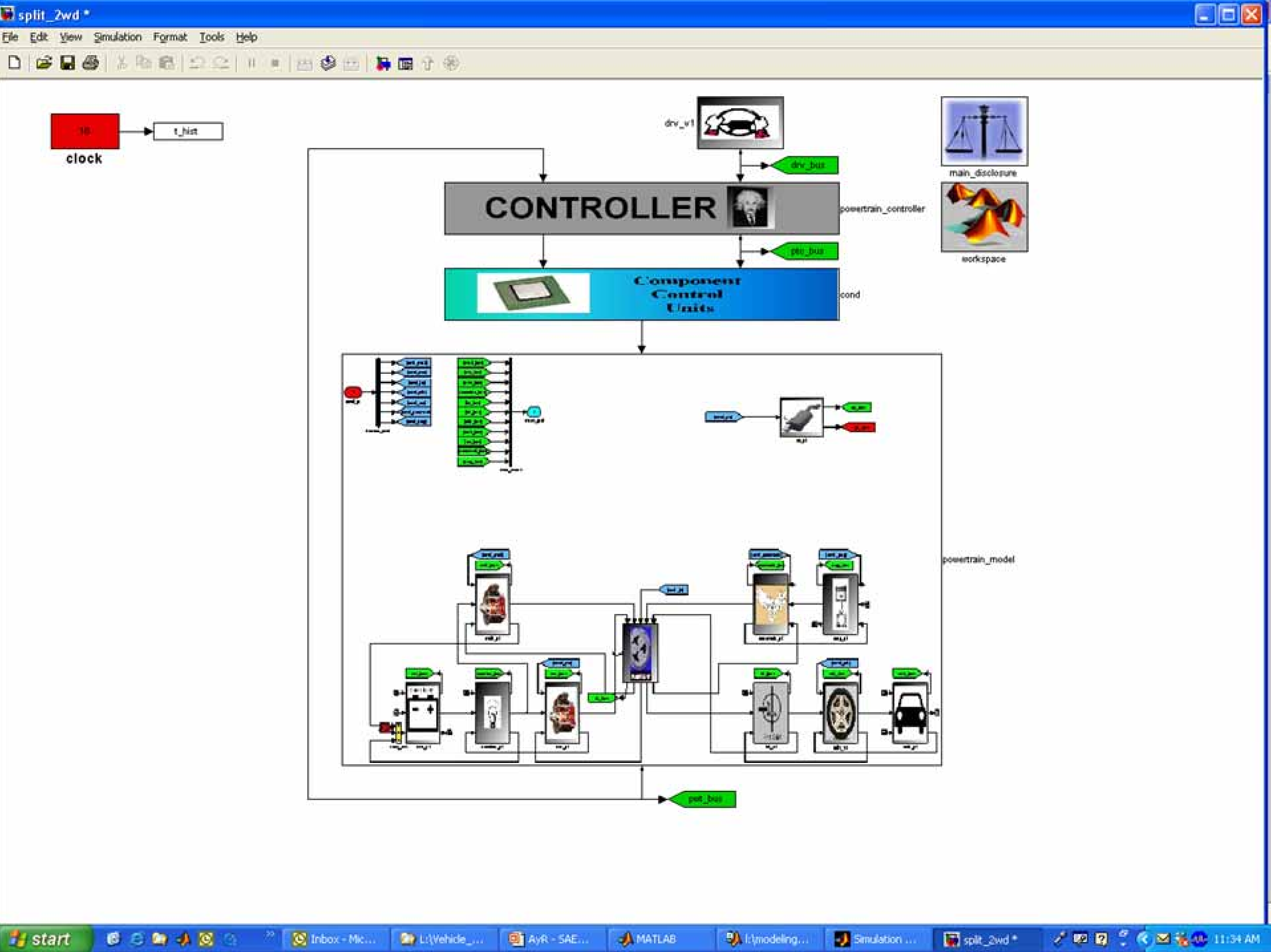
Final Drive
fd_v1
wh_v1
veh_v1
start
MATLAB
11:34 AM

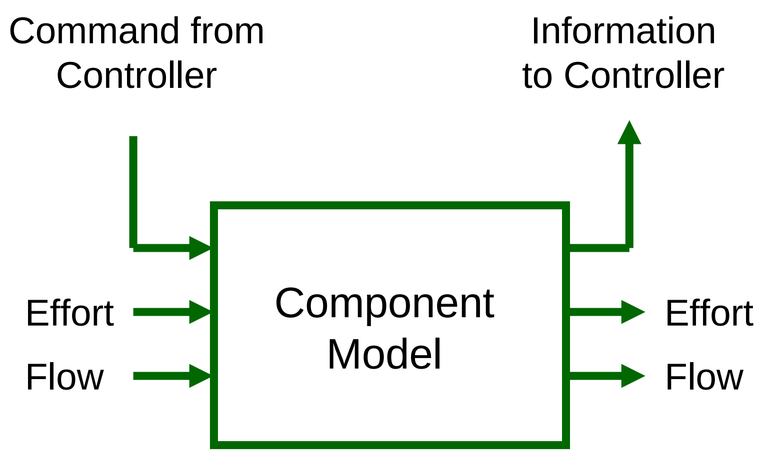

split_2wd *
File Edit View Simulation Format Tools Help
clock
t_hist
drv_v1
drv_bus
main_disclosure
CONTROLLER
powertrain_controller
ptc_bus
workspace
Component
Control
Units
cond
powertrain_model
pwt_bus
start
Inbox - Mic...
L:\Vehicle_...
AyR - SAE...
MATLAB
I:\modeling...
Simulation ...
split_2wd *
11:34 AM

Configuration Structure Allows Drivetrain Building and Manages Compatibilities

Structure	Field name	Description
config	name	Name of the powertrain (example: "par_2wd_p2_ct")
	pwt	Hybrid Family (example: "Parallel Hybrid")
	axle	Number of axles (example: "2 wheel drive")
	trans	Transmission technology (example: "ct" for continuous variable transmission)
	name_compo	Component used in the powertrain (example: {'drv', 'eng', 'mc', 'wh'…)
	ver_compo	Component versions the user can select
	pos_compo	Location of each component in the powertrain and component it is connected to
	prop_strat	Control strategies available for the powertrain.
	trs	Transient needed for the powertrain

Model Complexity Selection Facilitated by Generic Component Model Format

- Models follow Bond Graph principle
- Consistent input/output nomenclature
- Plug-and-play component models
- Configuration easy to visualize in block diagram code

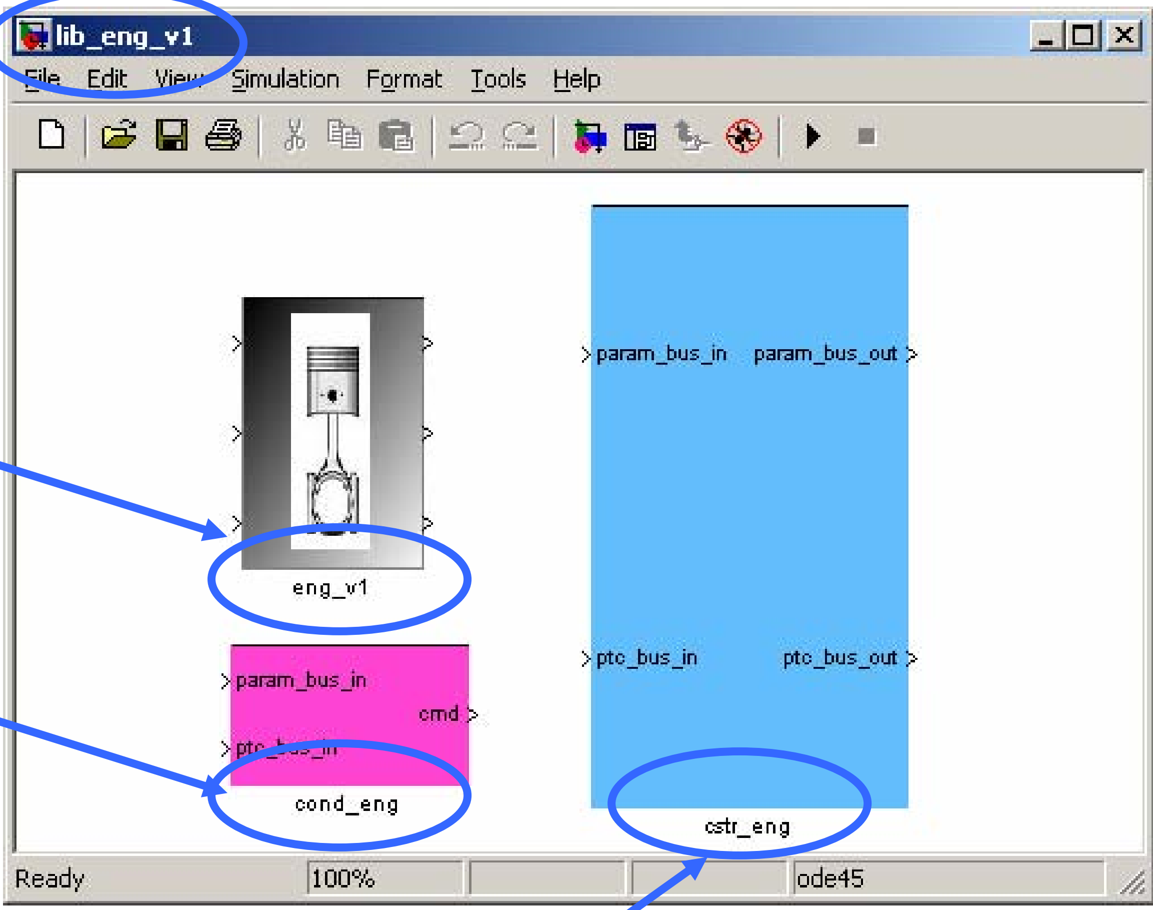


Mechanical Component
Effort = Torque
Flow = Speed

Electrical Component
Effort = Voltage
Flow = Current

Model Maintenance Ensured Using Libraries

Name of the Library



Simulink Model Version

Signal Conditioning Block

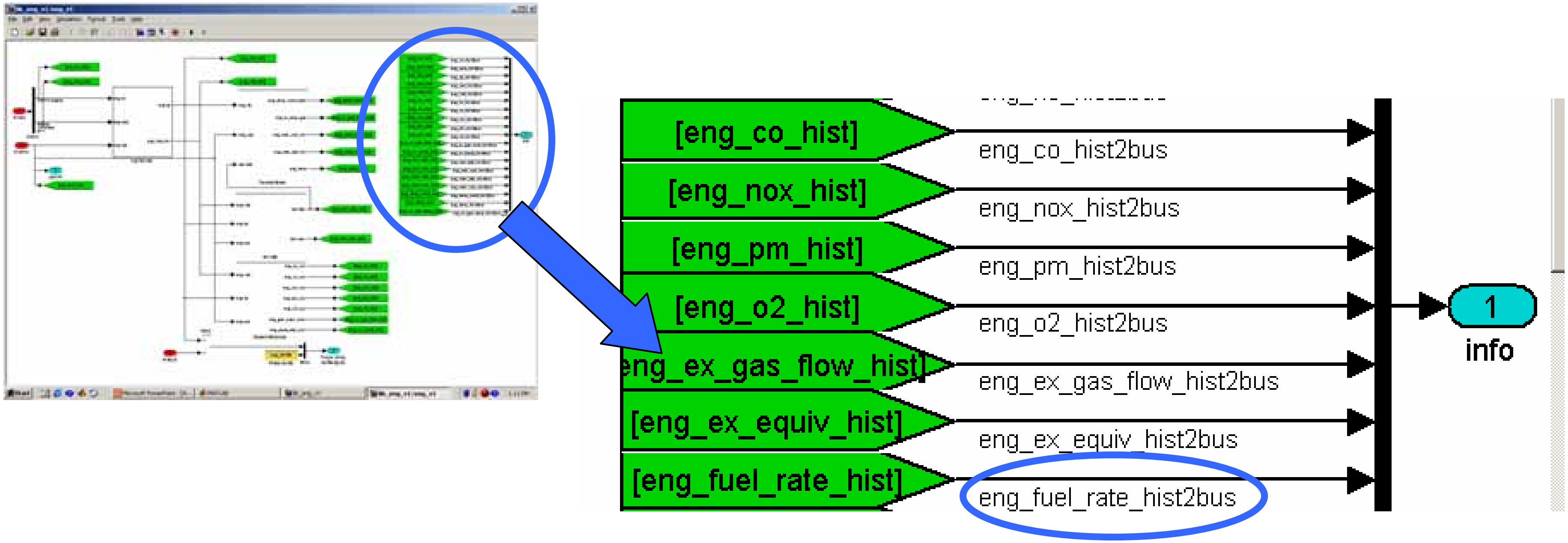
Constraints Block

Parameter Names Follow Nomenclature

- Based on three parts:
  - Type of component (e.g.: eng = engine)
  - Type of data (e.g.: trq = torque)
  - Complement of information (e.g.: max = maximum)
- All the model parameters and variables are composed using these three parts

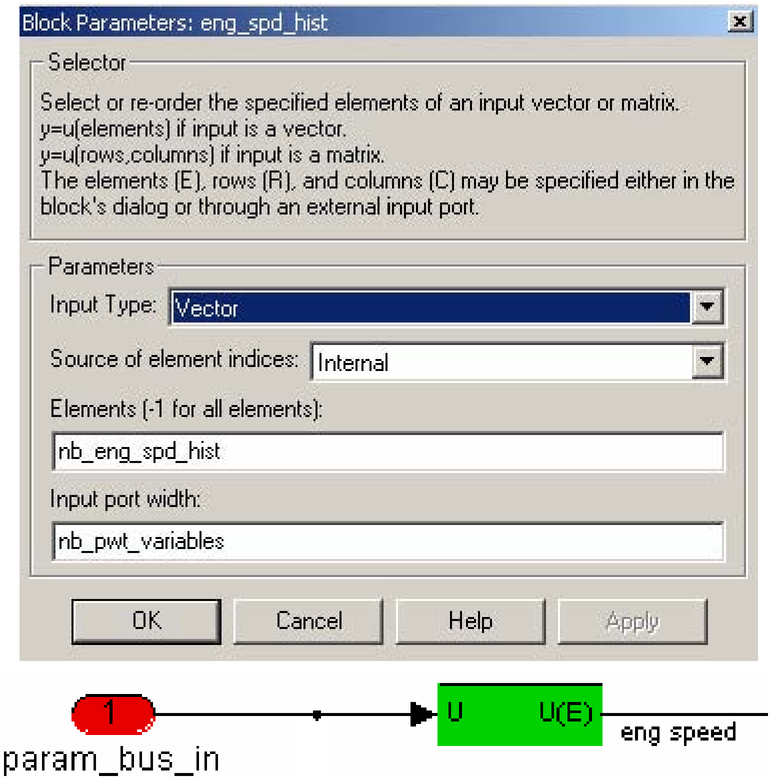
Parameter	Type of component	Type of data #1	Type of data #2
eng_spd_hist	"eng" for engine	"spd" for speed	
mc_volt_hist	"mc" for motor controller	"volt" for voltage	
ptc_eng_trq_max_hist	Engine information used in the controller ("ptc")	"trq" for torque	"max" for maximum

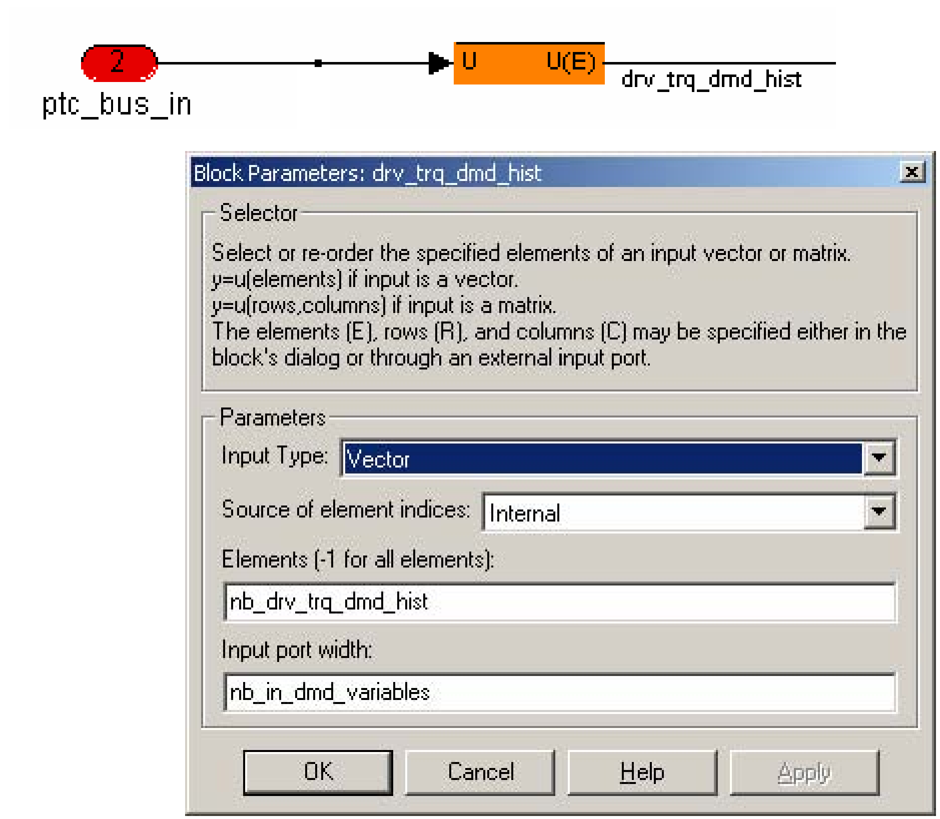
Mux Lines Used to Locate Parameters in Buses



Name of the line => “name_parameter”2bus

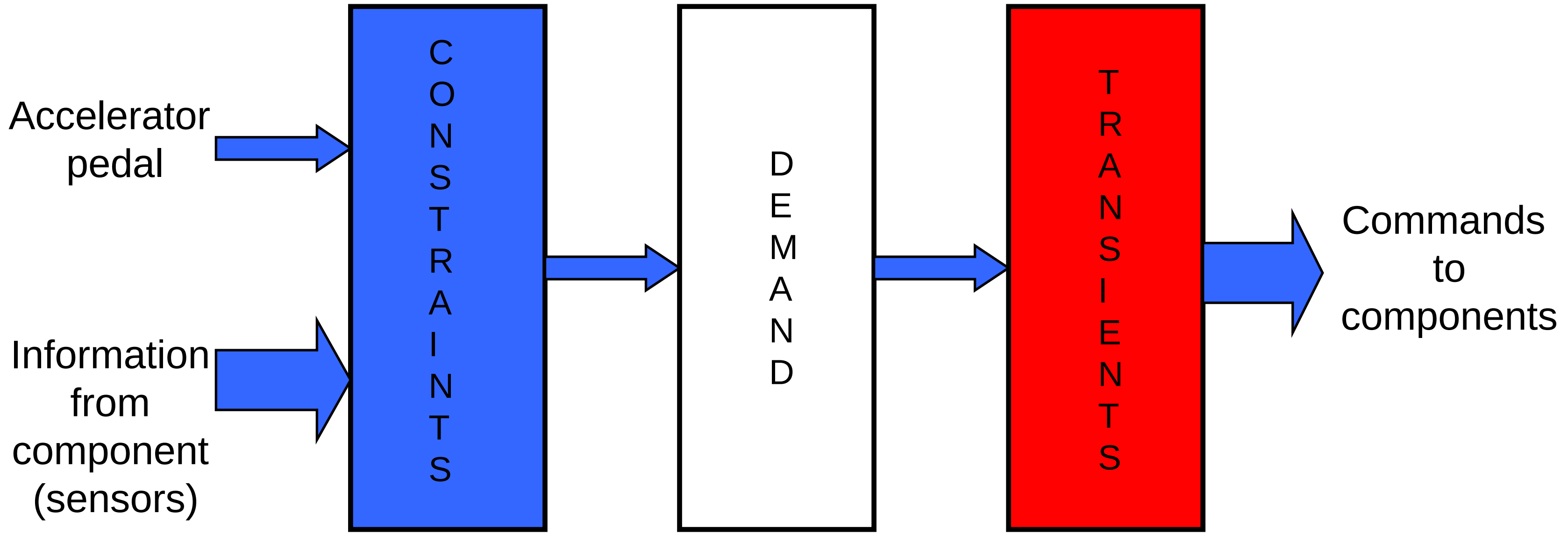
Accessing Parameters From Buses



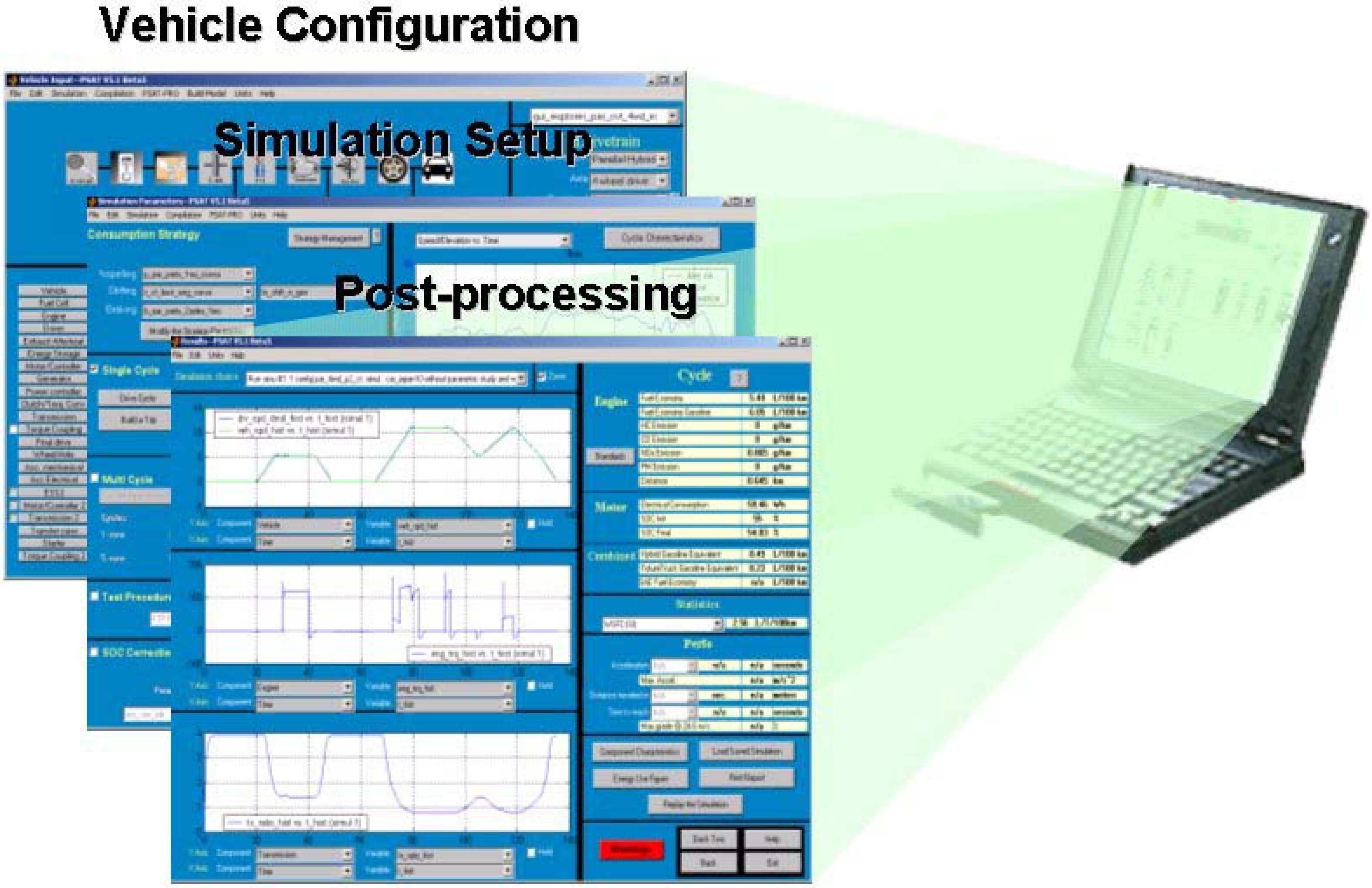


Generic Vehicle Powertrain Controller Organization

A generic organization common to all powertrains



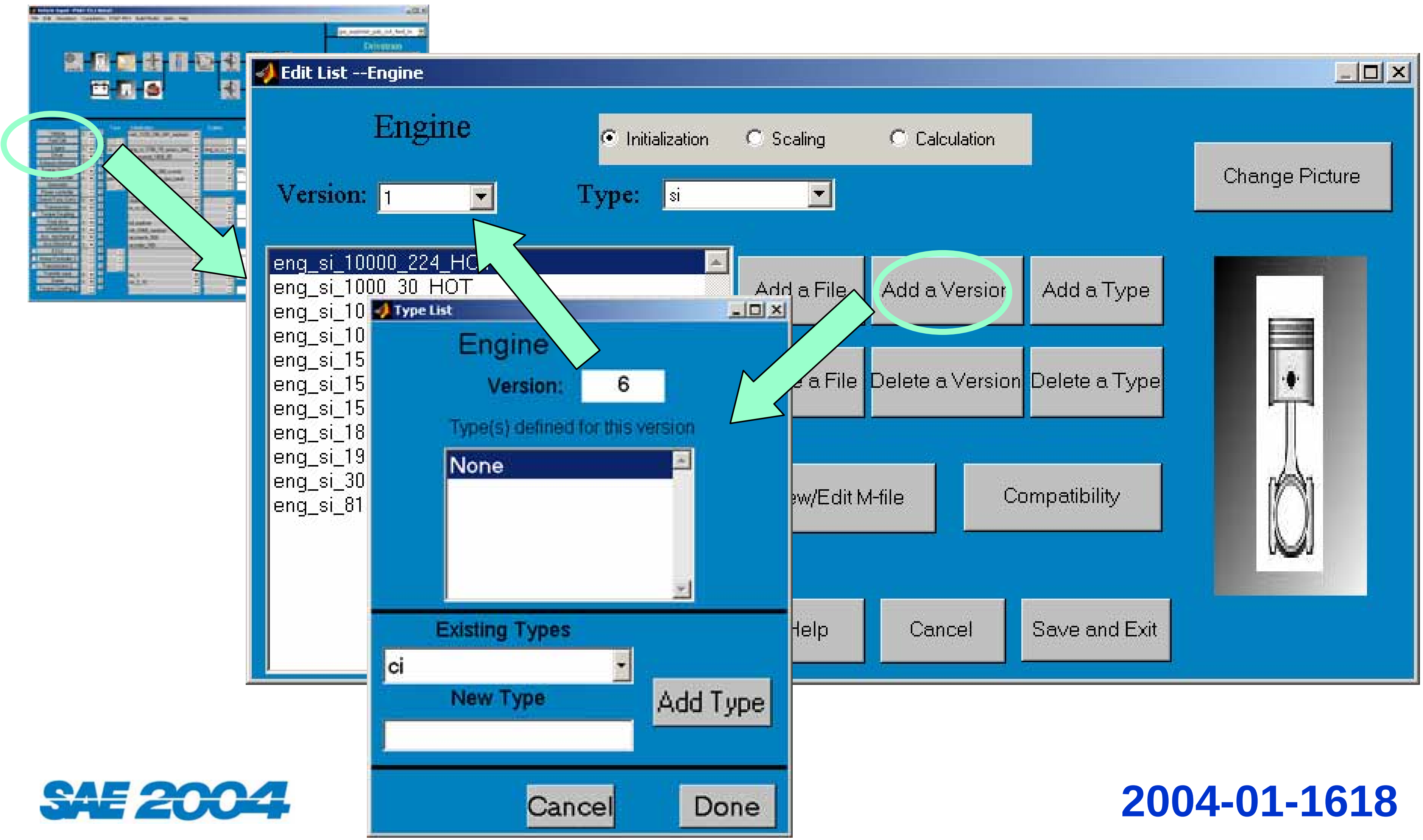
PSAT GUI



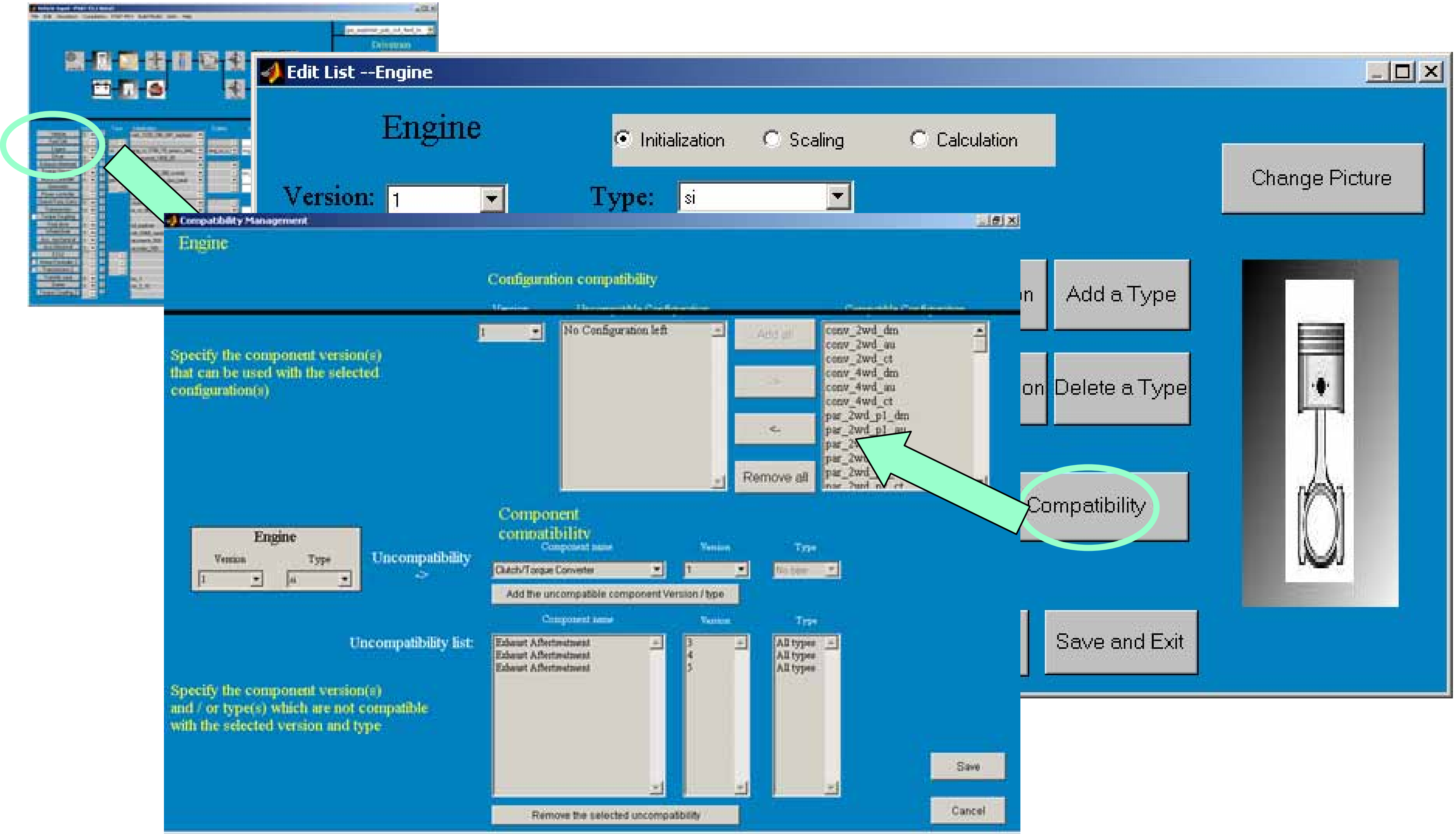
Model Structure List All the Users Choices from the Graphical User Interface

Field #1	Field #2	Field #3	Meaning
gui	size		Graphical user interface window size
units			Units used in PSAT (metric or english units)
drivetrain	name		This is the name of the model
	'component name abbreviation' (i.e : eng)	ver	Component version
		type	Component type (SI, CI…)
		init	Component initialization file
		scale	Component scaling file
		calc	Component calculation file
prototyping			used only with the optional PSAT-PRO
sim	cycle	run	ON when we choose to run a cycle
		number	Number of cycles
	acceleration	run	Acceleration test
strategy	conso	prop	Propelling strategy init. file & model
		shifting	Shifting strategy init. file & model
		braking	Braking strategy init. file & model
results	conso	ess_soc_init	Initial state of charge
		final_abs_soc	Final absolute state of charge
		fuel_econ	Fuel economy in miles per galon

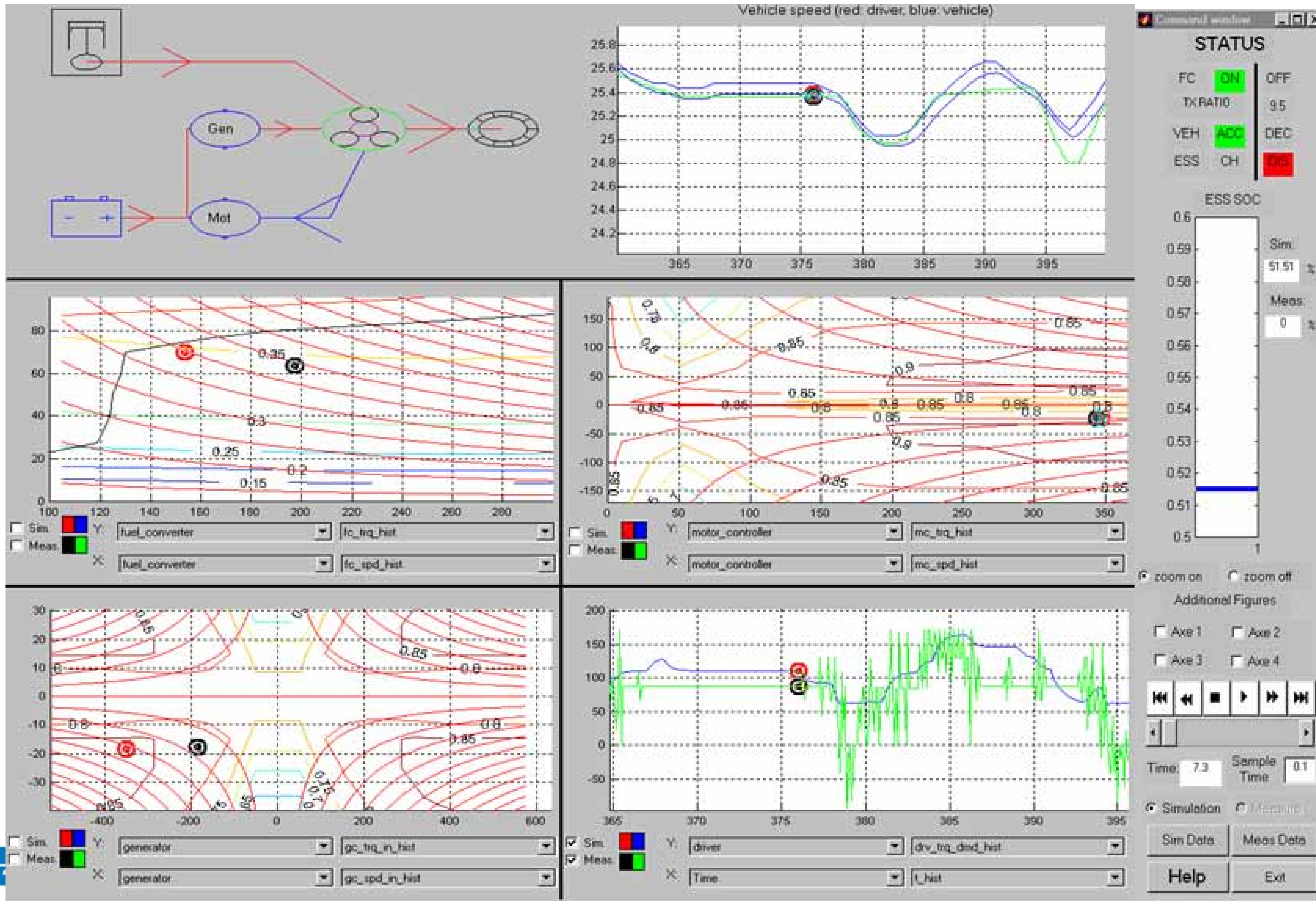
Proprietary Information Are Added Without Code Modification



Compatibility Is Managed For the Users



Specific Tools Developed To Visualize Results and Understand Behavior



Reusable Tools Ensure Resource Leverage

- Proprietary data set, component model and control strategies can be easily implemented thanks to:
  - Naming nomenclature
  - Generic component model format
  - Flexible GUI
- Large number of predefined configurations can be selected as the powertrain is built
- Flexible post-processing
- Most of the concepts can be applied to other tools

Contacts

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Philip Sharer psharer@anl.gov

Transportation website www.transportation.anl.gov

PSAT www.psat.anl.gov