

Chip simulation of automotive ECUs

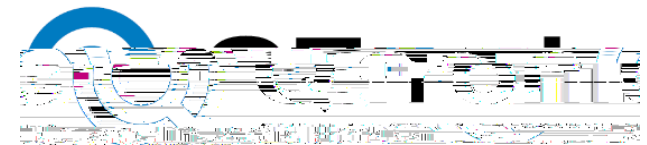
Jakob Mauss, QTronic GmbH

Matthias Simons, Daimler AG

9. Symposium

Steuerungssysteme für automobile Antriebe

Ulm, 12. - 14. September 2011



Chip simulation of automotive ECUS

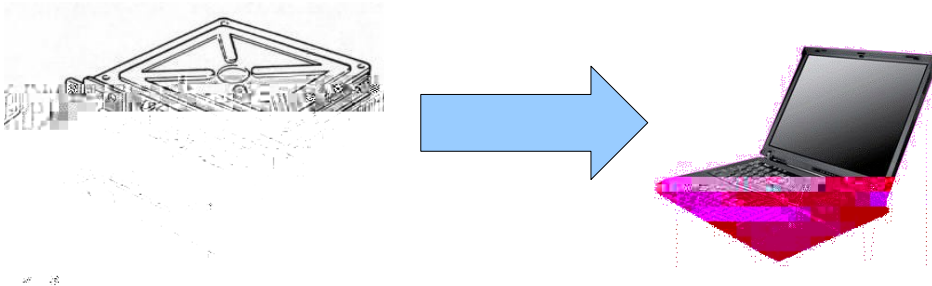
&. Motivation

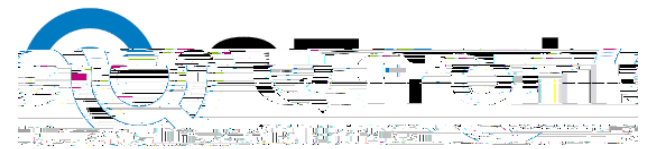
\$. Setting up a simulation

+. Performance

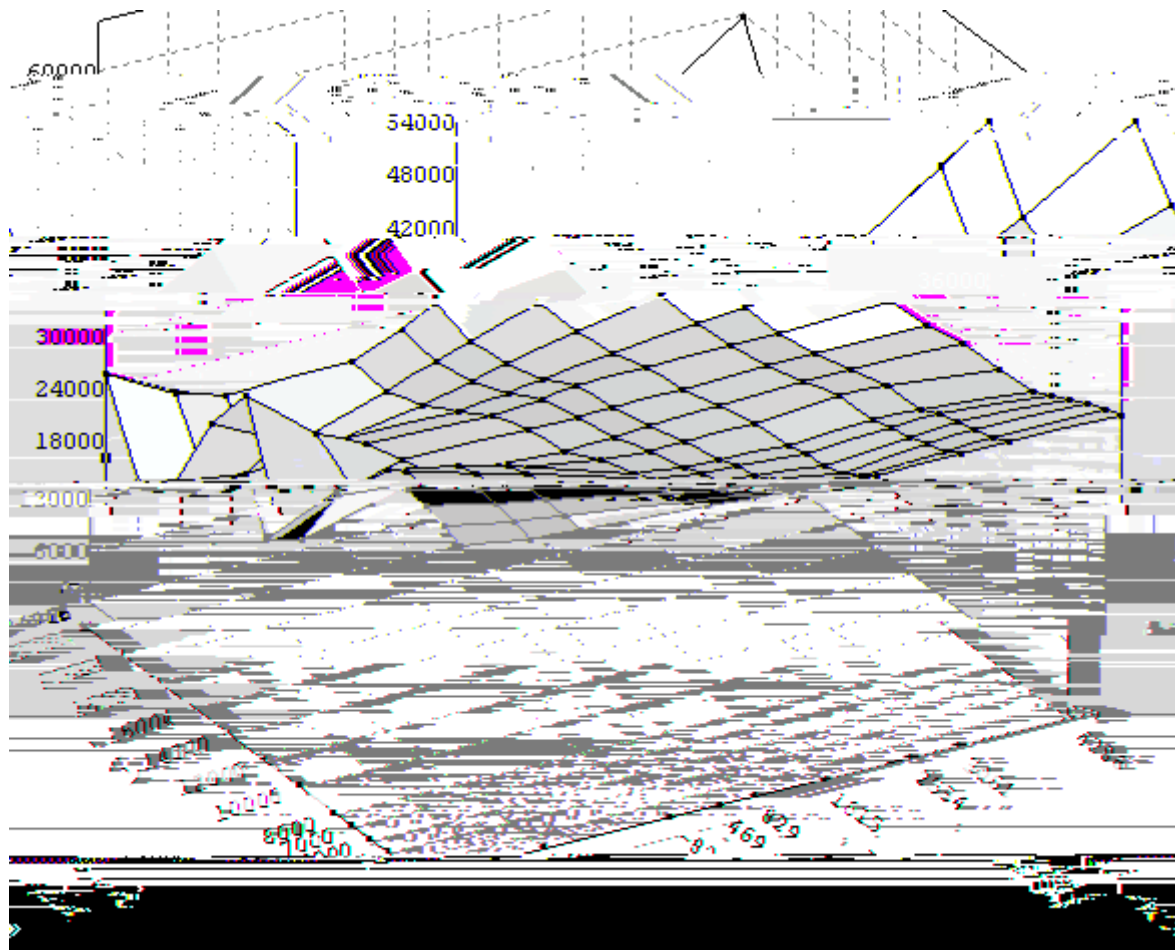
- . Limitations

/. Conclusion



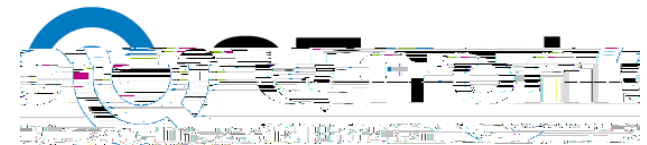


ECU: more than 30.000 software parameter



8039A3C0	00 80 00 80	00 80 00 80	00 80 00 80	00 80 00 80	00 80 00 80	00 80 00 80	00 80 00 80
8039A3D0	00 80 00 80	00 80 00 80	00 80 00 80	00 80 00 80	00 80 00 80	00 80 00 80	00 80 00 80
8039A3E0	00 80 00 80	00 80 00 80	00 80 00 80	00 80 00 80	00 80 00 80	00 80 00 80	DA 10
8039A3F0	09 F5 18 F8	42 FA AE FF	D5 01 3D 03	4F 06 E6 09			

A screenshot of a CAN bus data capture tool. The top part shows a list of CAN frames with their IDs and data bytes. The frame ID 8039A3E0 is highlighted with a red box, and its data bytes are 09 F5 18 F8 42 FA AE FF D5 01 3D 03 4F 06 E6 09. Below this, there are several rows of data, each representing a CAN frame. The data bytes are displayed in hexadecimal and ASCII. The bottom part of the screenshot shows a waveform of the CAN bus signal, with the data bytes corresponding to the frames above it.

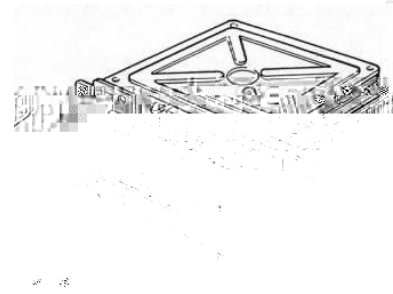
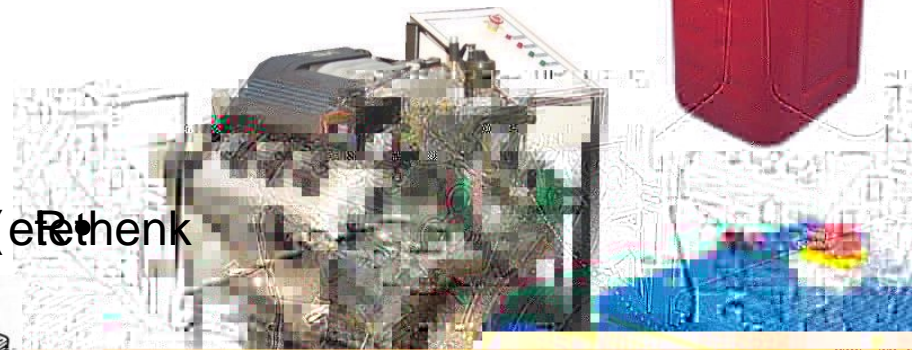


Online Calibration

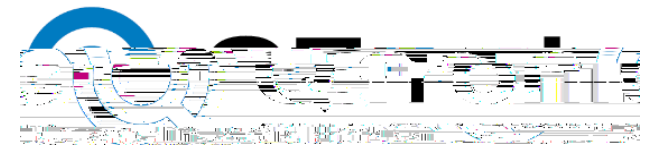
tune more than +%.%%%) ' * parameter
 # One by the 1) M, not by the supplier of the) ' *
 %ross to ay
 # automate optimization of stationary states
 # real-time test rig or (vehicle based on the real) ' *
 # , ' based engine and) ' * both simulated, e.g. in Simulink

Requirements

real-time test rig
 # limited reproducibility
 # expensive (investment, operation)
 # slow real time
 # , ' 3 re(erse enco... Die(e... k... ers... er... henk



! otivation

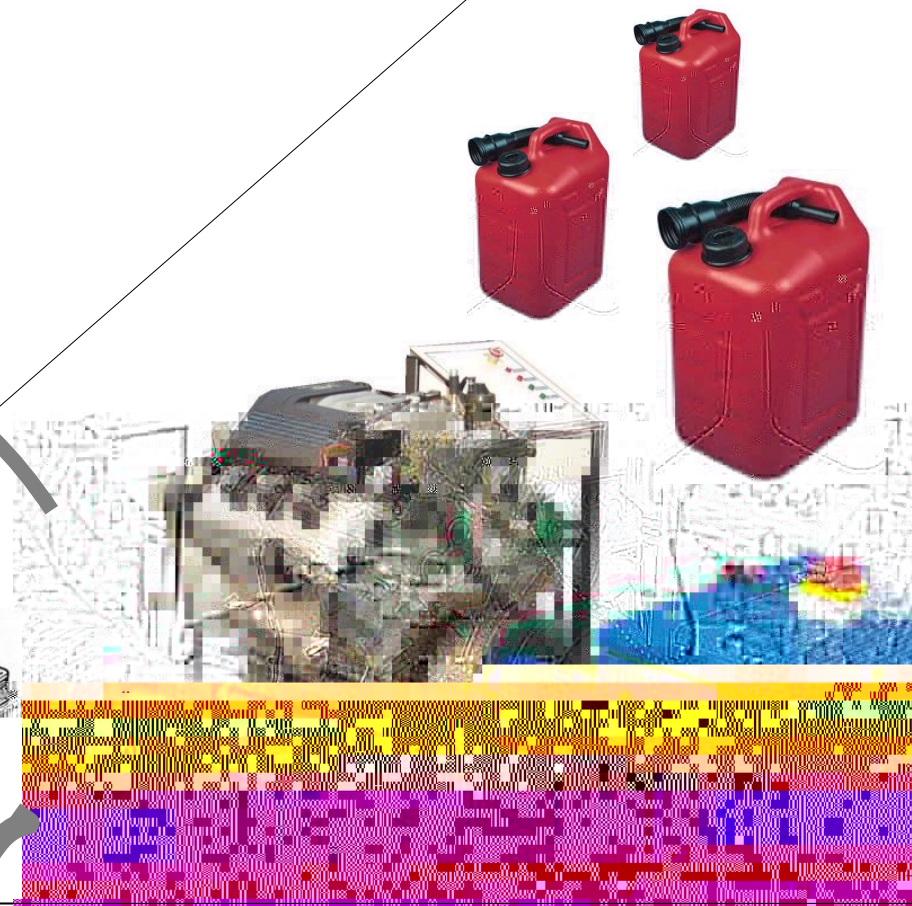
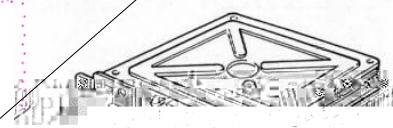
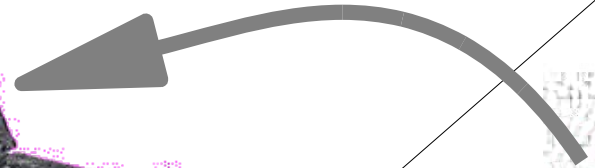


& ea

mo(e engine calibration 5an0 other 0e(elopment tasks6
rom test rig to , '

'enefit

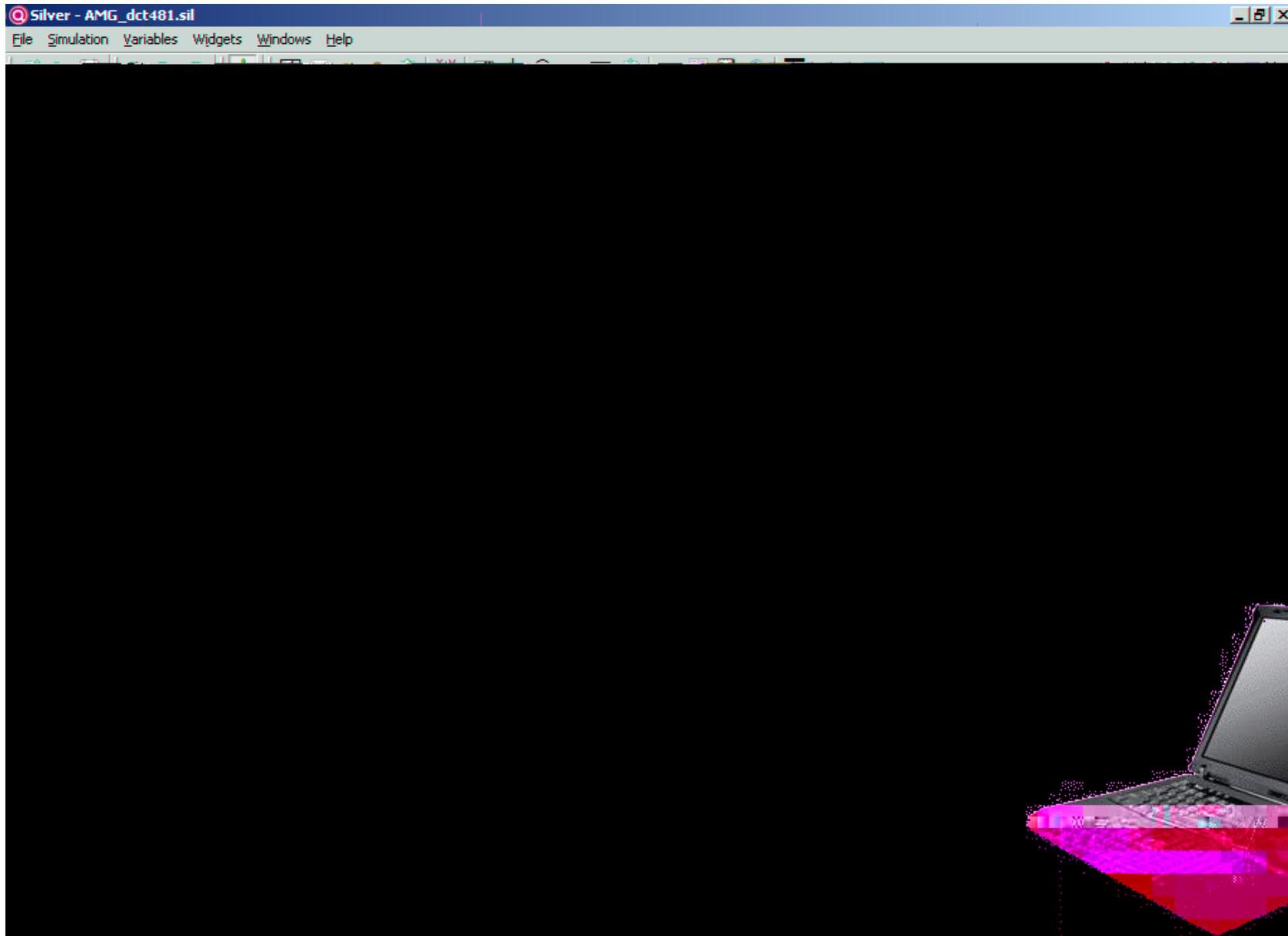
- # simulation runs much aster than real time
- # enables use o mathematical optimi2ation





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Example) *CU Control Software in Silver



Setting up a VeriCore simulation



- &. Write spec.t4t to specify functions to run
- \$. step and debug the simulation in Sil(er) mode
- +. generate fast running Simulation or Sil(er) mode runs without a shell

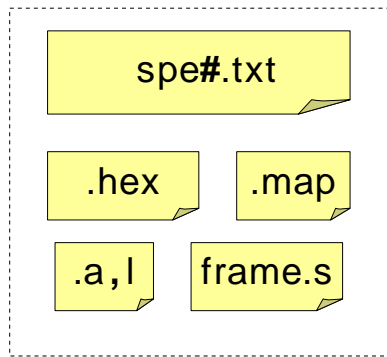
Setting up a *riCore simulation



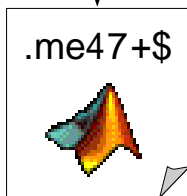
- &. Write specification to specify functions to run
- \$. step and debug the simulation in Silver module
- +. generate test running Silver module without additional help

```
01 # specification of function or Silver module
02 hex_file(m12345.hex, TriCore!1.3.1"
03 a2l_file(m12345.a2l"
04 map_file(m12345.map"      # a T#S$%&' or '&( map file
05 frame_file(frame.s"      # assembler code to emulate *T+S
06 frame_set(ST-!S%/-, 10" # Silver step size in ms
07 frame_set(T-2T!ST#*T, 0xa0000000" # location of frame code
08
09
10 # functions to be simulated, in order of execution
11 task_initial(#5 6-!ini"
12 task_initial(#5 6-!inis7n"
13 task_triggered(#5 6-!s7n, trigger!#5 6-!s7n"
14 task_periodic(#5 6-!20ms, 20, 0"
15 task_periodic(#5 6-!200ms, 200, 0"
16
17 # interface of the generated function or Silver module
18 a2l_function_inputs(#5 6-"
19 a2l_function_outputs(#5 6-"
20 a2l_function_parameters_defined(#5 6-"
```

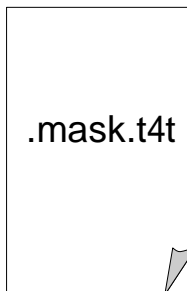
"enerate S-unction in ! . * / . ' 0Simulink



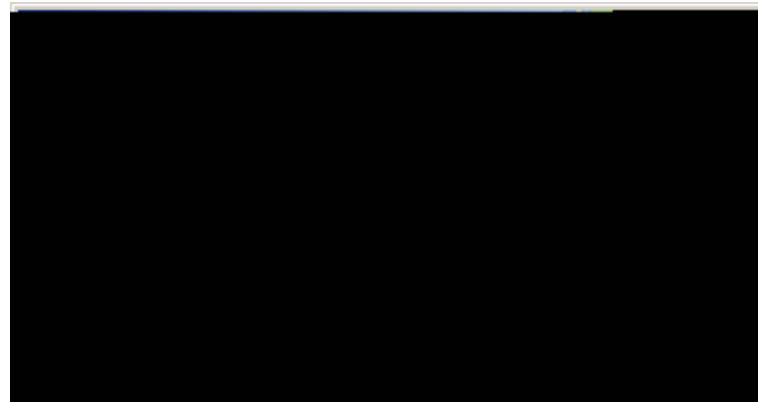
t#\$uil



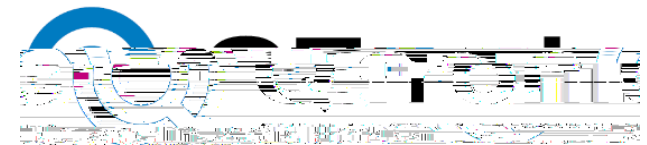
MAT.A " ;Simulink
S# unction
+0 !&%S



0e ault (alues or
characteristics rom
H) < ile as m script,
mask or S# unction
block an0 similar
Simulink snippets



characteristics turne0 into
MAT.A " 7orkspace (ariables
rea0 by S# unction
may be mo0i ie0 by script

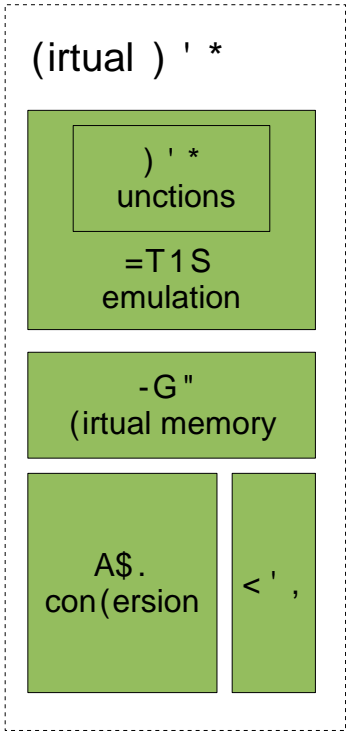


spe#.txt

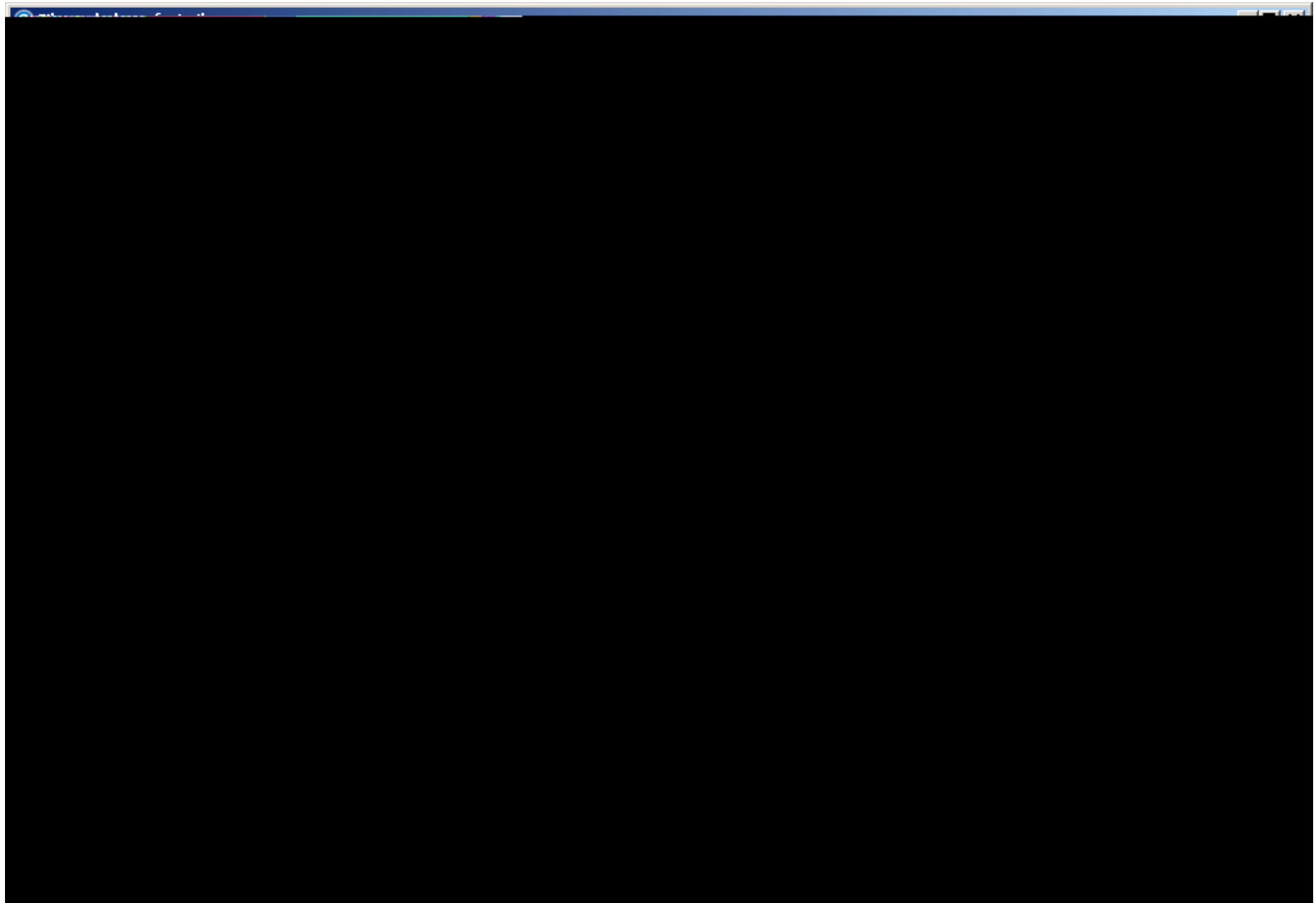
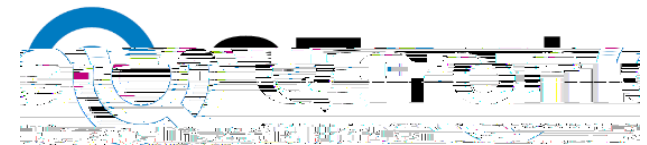
.hex

.map

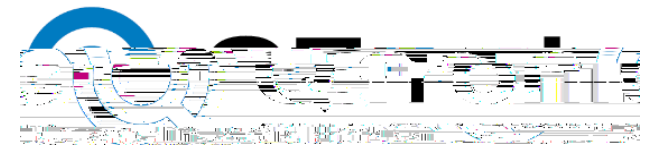
frame.s



1 irtual ECU runnin" in Silver: ! E213



Performance and Limitations



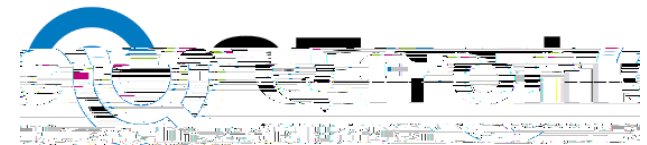
4 uncomplex function for a measure scenario 3.6 minutes

target	execution time	! %S
Sil(ering in debug mode)	9.9. & / sec	%. - &
generate0 Sil(ering module or MAT.A"; Simulink S: unction	9.+ % sec	-%. ?%
M) D&@ 7ith T' &@9@, &?% Mh2	\$&%. % % sec	\$@%

Limitations

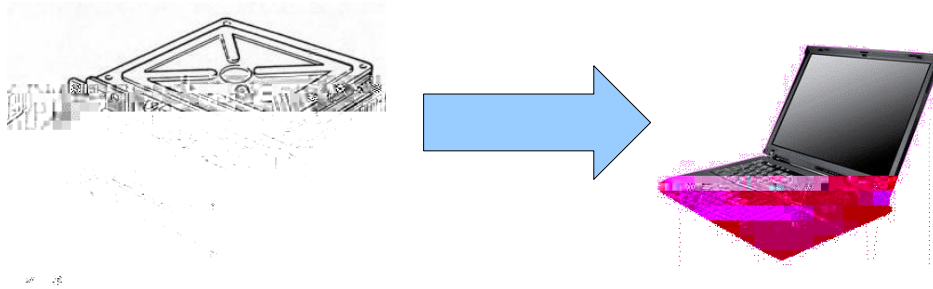
- # instruction accurate, but not cycle accurate
- # based on TriCore specification; silicon bugs are not simulated
- # , ' , , ' A> controllers and other on chip peripherals not modeled

Summary



ECU simulation on 7 in ows %C

- # 7ithout e4pensi(e re(erse engineering
- # 7ithout access to) ' * source files
- # base0 on H) <, MA , an0 A\$. ile
- # lo7 7ork e ort or mo0eling
- # high accuracy o mo0el
- # application e4ample3 automate0 calibration



- # 7orks or Tri ' ore processors3 T ' &@9B, T ' &@9@, T ' &@9?, ...
- # per ormance3 -% M9 , S