SIEMENS

Solid State Direct Drive RF Linac: Control System

T. Kluge, M. Back, R. Fleck, U. Hagen, O. Heid, M. Hergt, T. Hughes, R. Irsigler, J. Sirtl
Corporate Technologies
Siemens AG, Erlangen, Germany
H. Schroeder
ASTRUM IT GmbH, Erlangen, Germany

Solid State Direct Drive RF Linac: Control System

SIEMENS

Overview

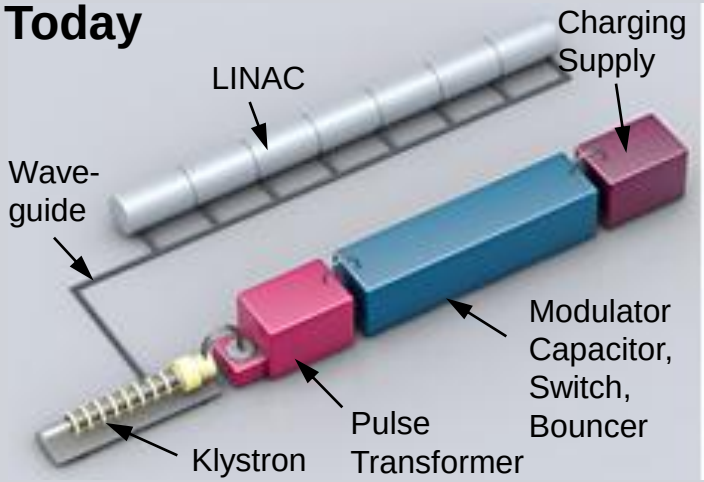
- Motivation
- RF Module Concept
- Control System Context
- Control System for Power Injection Tests
- Digital Control System
- Results
- Summary and Outlook

SIEMENS

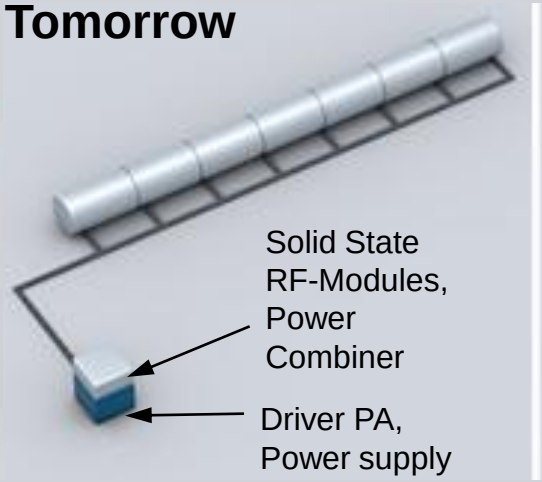
Motivation

- Electromagnetically coupled resonating cavities of traditional LINACs are driven by a single (or few) external RF power source connected via a waveguide and power couplers.
- Traditional RF power sources (e.g. Klystrons) can be replaced by high power SiC solid state RF-modules to enable compact system designs.
- Two implementation phases are planned

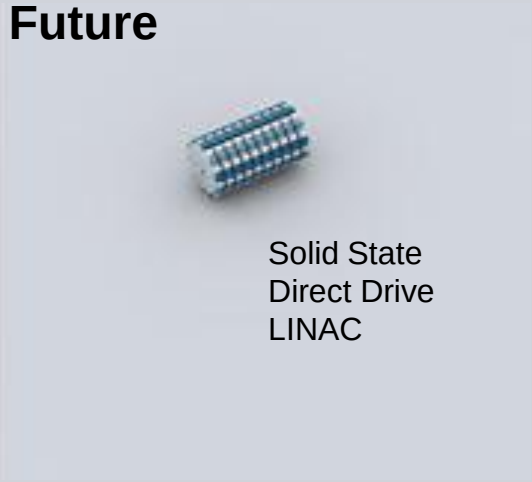
Today



Tomorrow



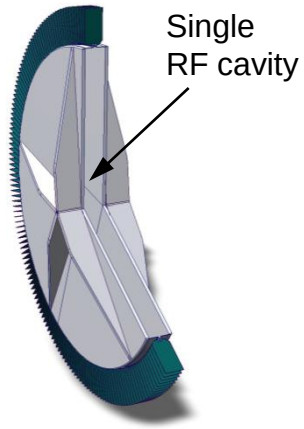
Future

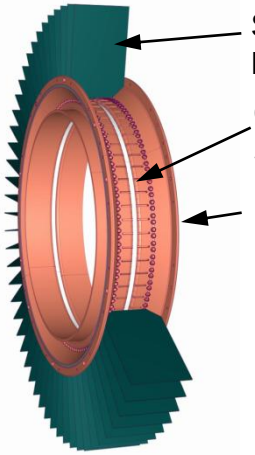


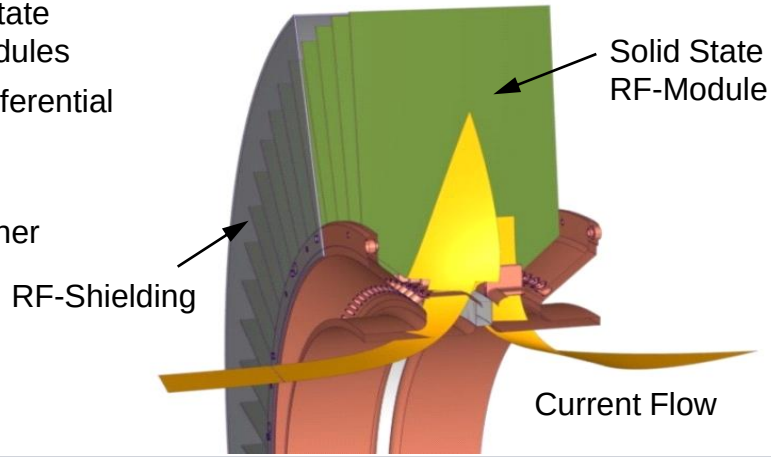
SIEMENS

Benefit of Solid State Direct Drive Concept

- Distributed RF-source for each cavity ➔ better reliability, better maintenance
- Simple scalable power levels ➔ lower cost, better maintenance
- Independent phase and power control in each cavity ➔ higher flexibility
- No external RF-source, waveguide or mode couplers ➔ lower cost, low footprint
- High efficiency of RF-Modules ➔ lower operation cost





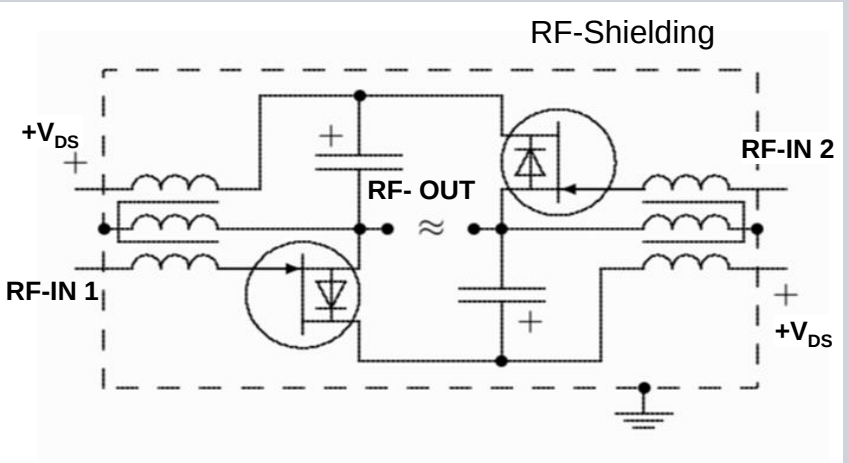


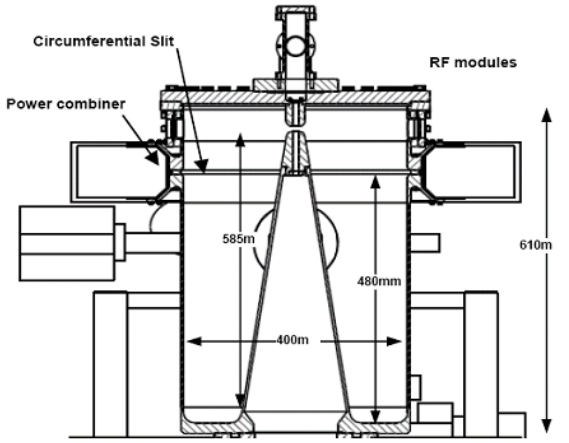
SIEMENS

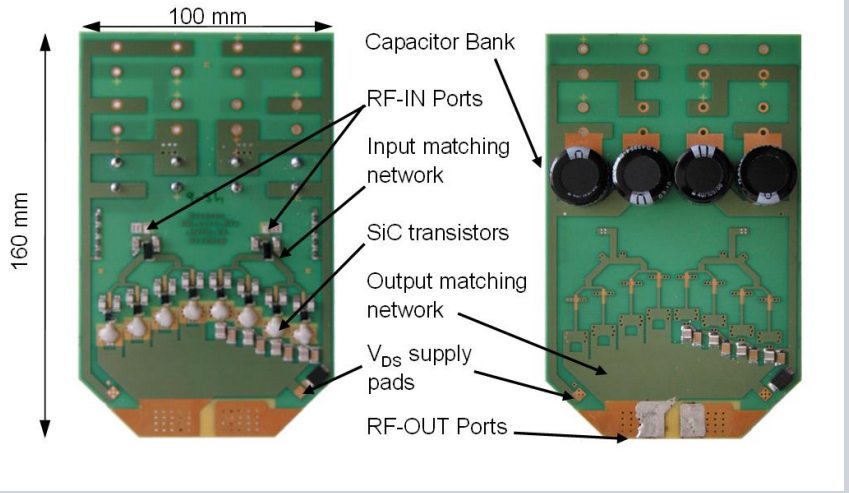
Solid State Direct Drive RF-Module

- Parallel push-pull topology (circlotron)
- 2-layer FR4 board
- 8 SiC transistors per RF-module

See Irsigler R. et al, 3B-9, PPC11, Chicago IL, USA

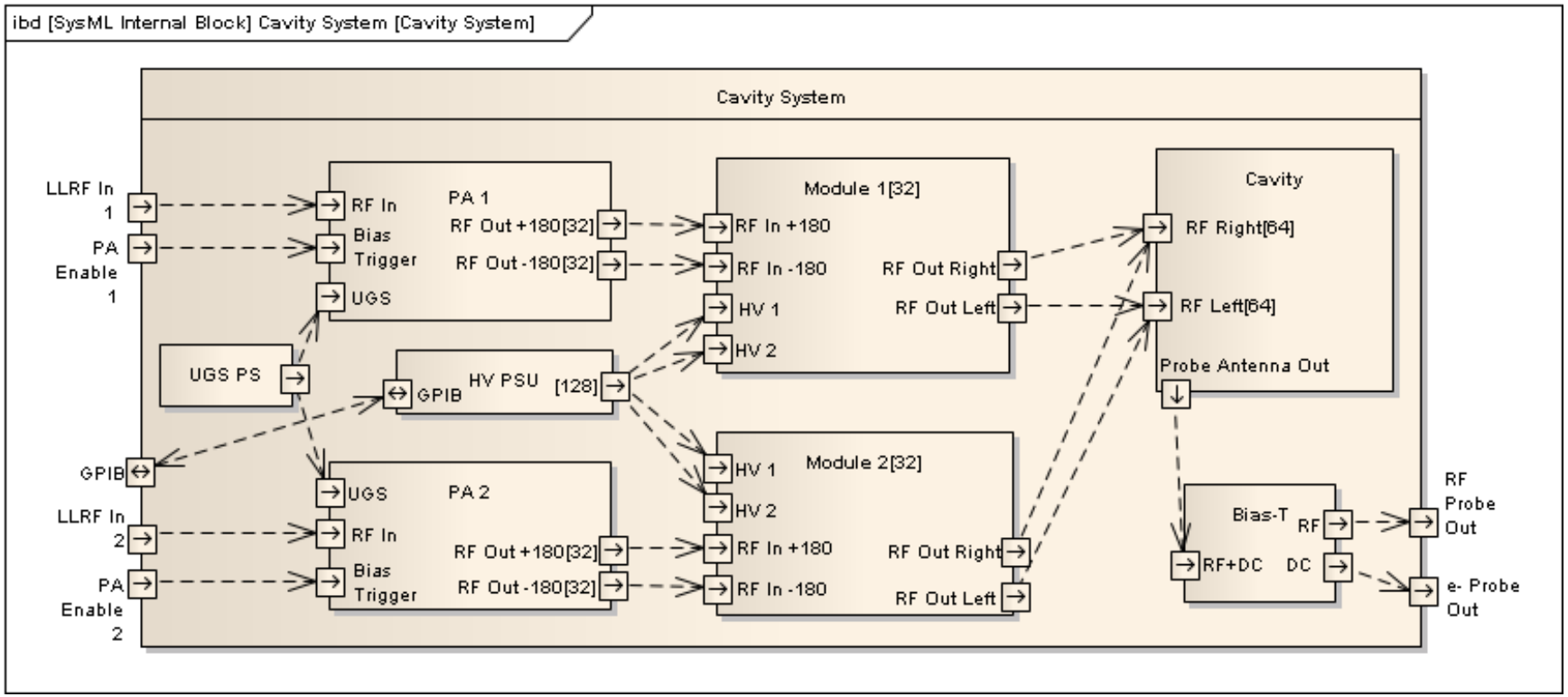






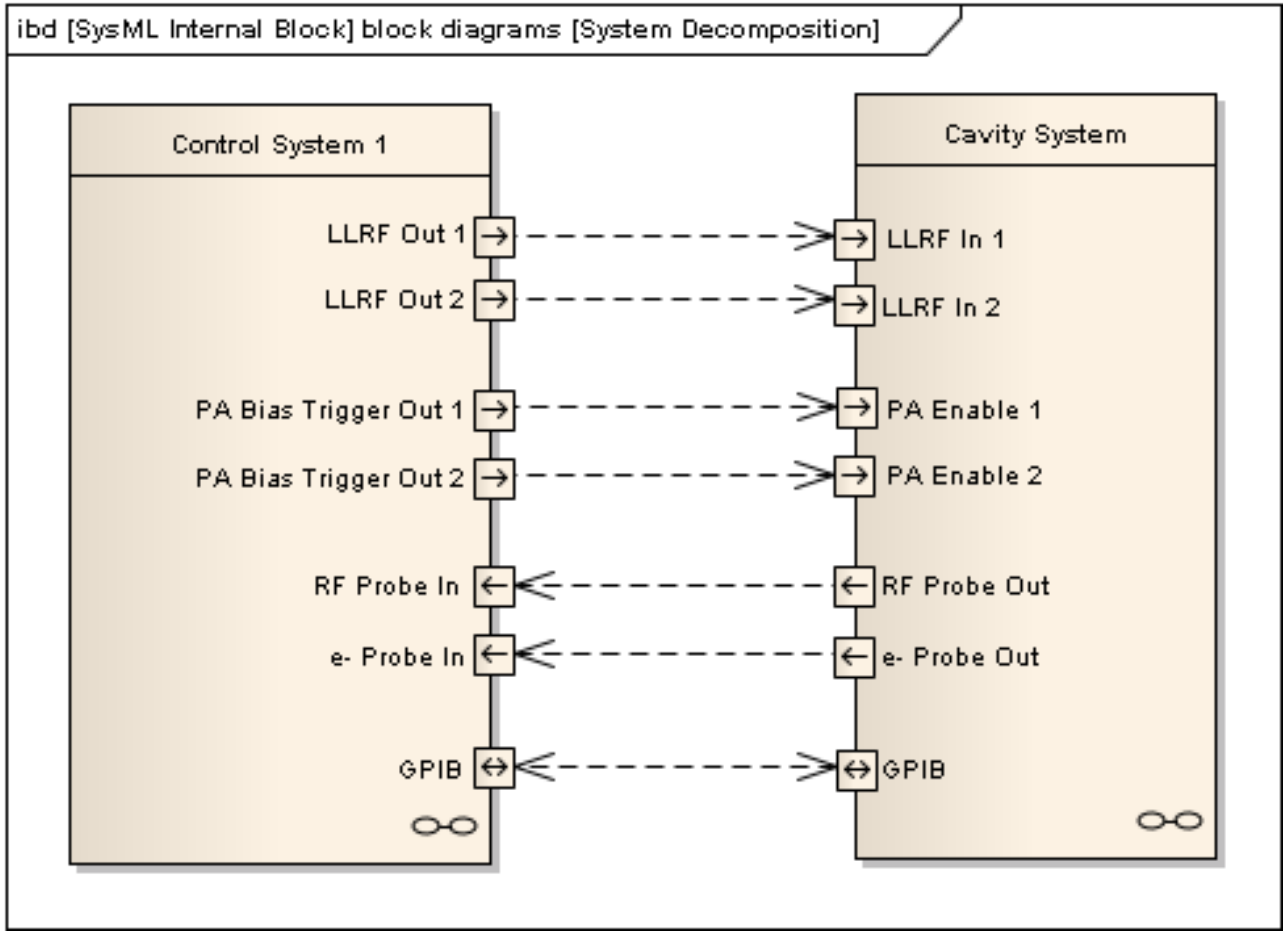
SIEMENS

Cavity (Sub-)System



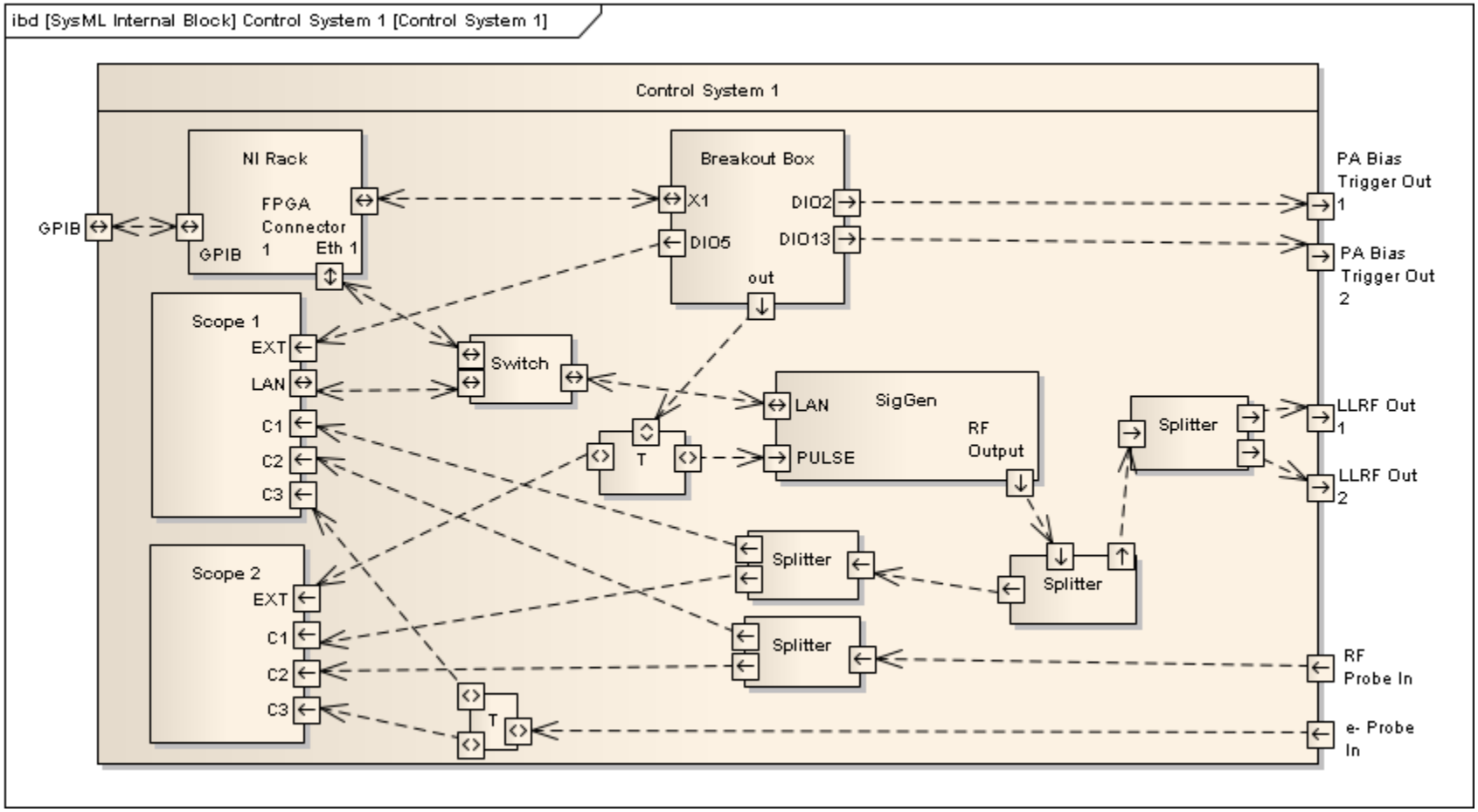
SIEMENS

System Decomposition

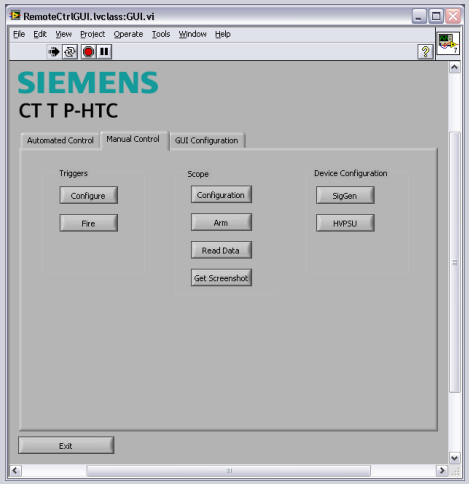


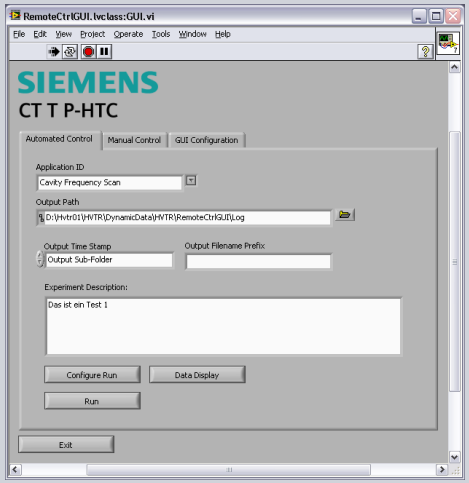
SIEMENS

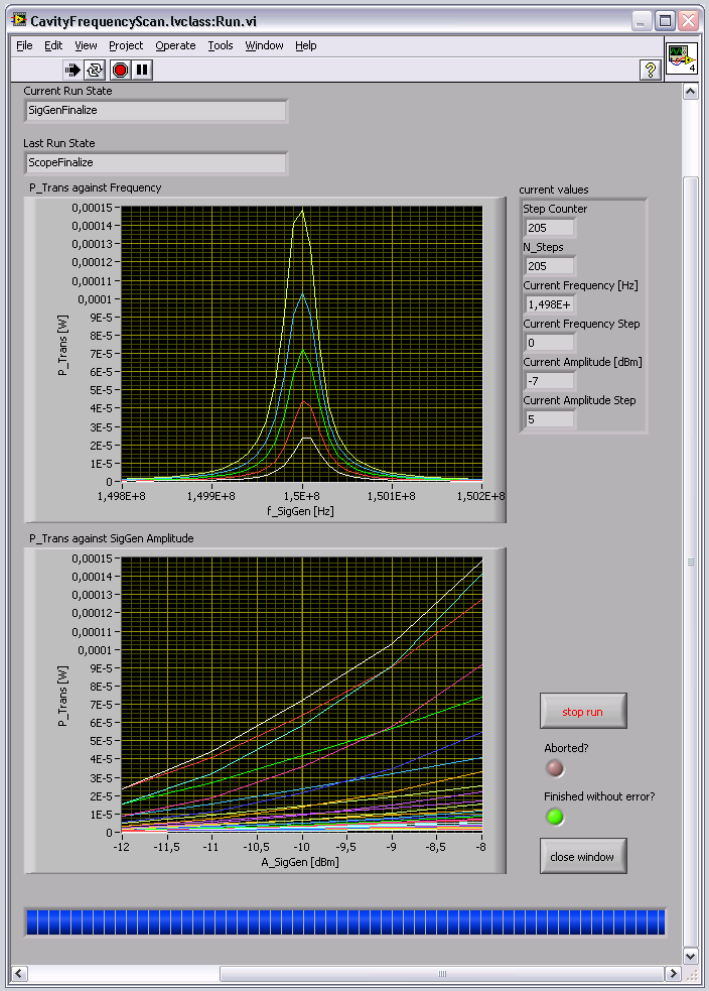
Control (Sub-)System for Power Injection Tests



Control Software







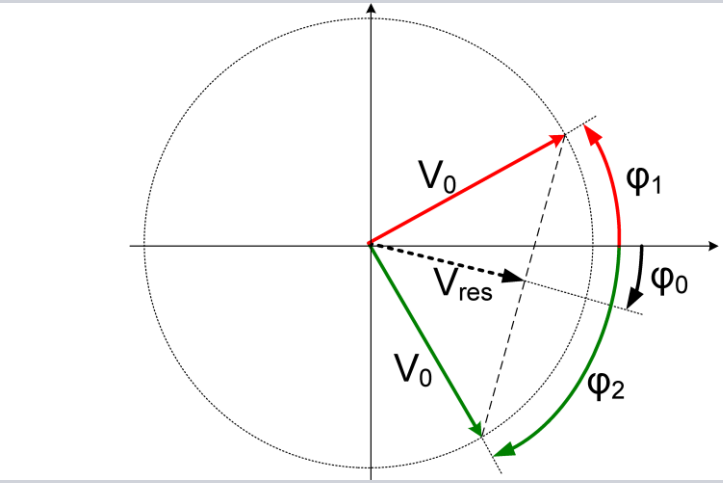
Outphasing for E-Field Amplitude Control

- RF modules are nonlinear and time variant devices:
- SiC transistors heat up
- Capacitors discharge

- RF modules have maximum efficiency at maximum output power

- Cavity slot acts as a power combiner

- Two groups of modules with independent LLRF signals



$$V_{res} = V_0 \cos\left(\frac{\varphi_1 - \varphi_2}{2}\right)$$

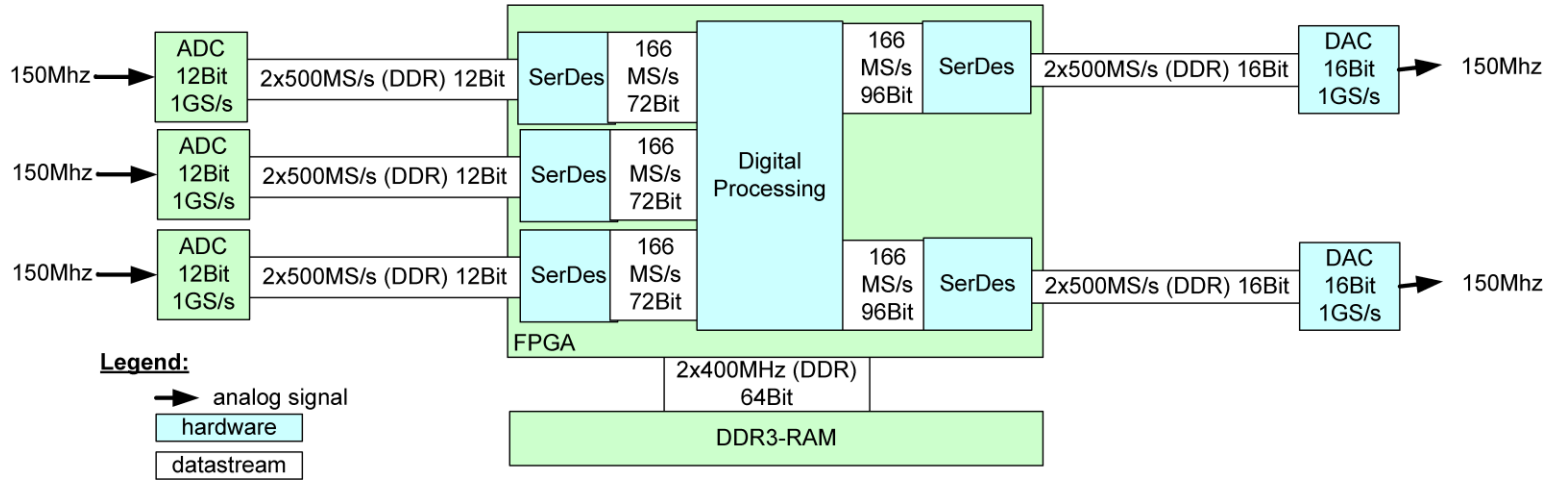
$$\varphi_0 = \frac{\varphi_1 + \varphi_2}{2}$$

SCCRT (Subsystem Cavity Controller Real Time) Design Goals

SIEMENS

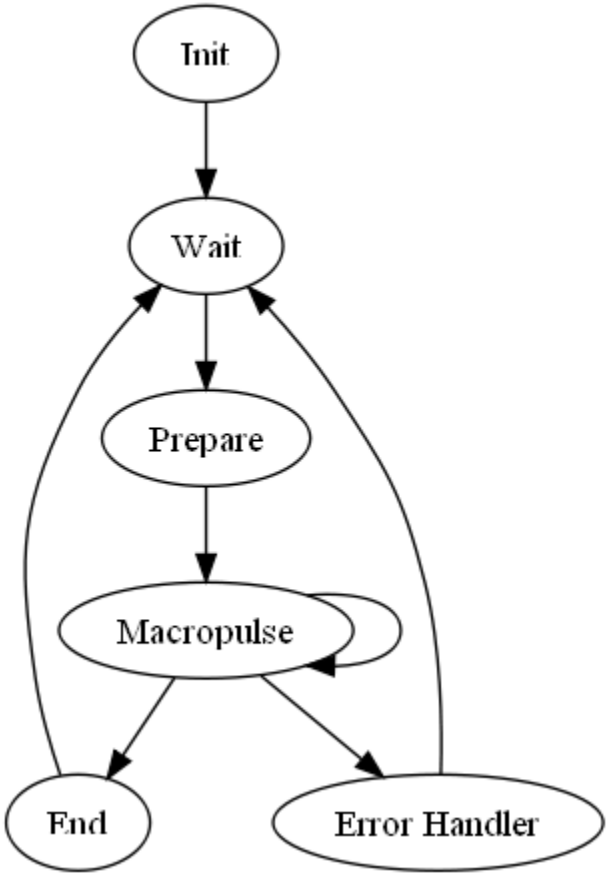
- 1GHz sampling rate for ADCs and DACs
- 3x 16bit ADC
- 2x 12bit DAC
- 10 input triggers (1ns resolution)
- 10 output triggers (1ns resolution)
- 166MHz 6-to-1 res 1-to-6 SerDes

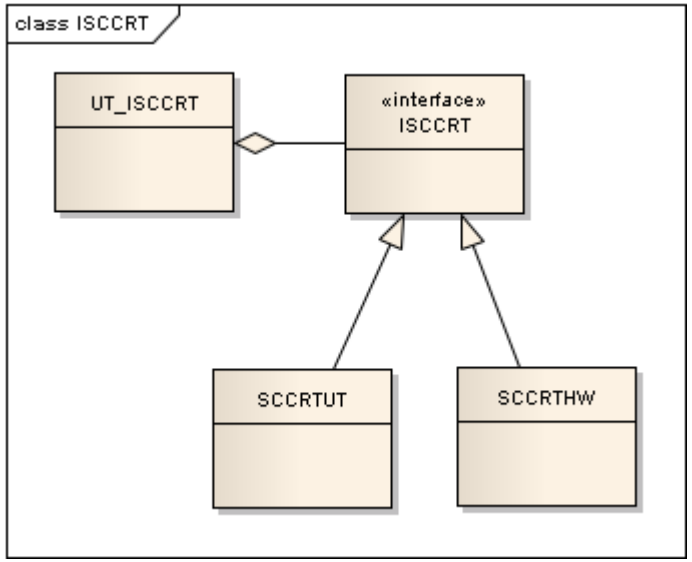
See Sirtl J. et al, MOPC152, IPAC11, San Sebastian, Spain



SCCRT first revision
State Machine and LabVIEW Object Oriented Driver

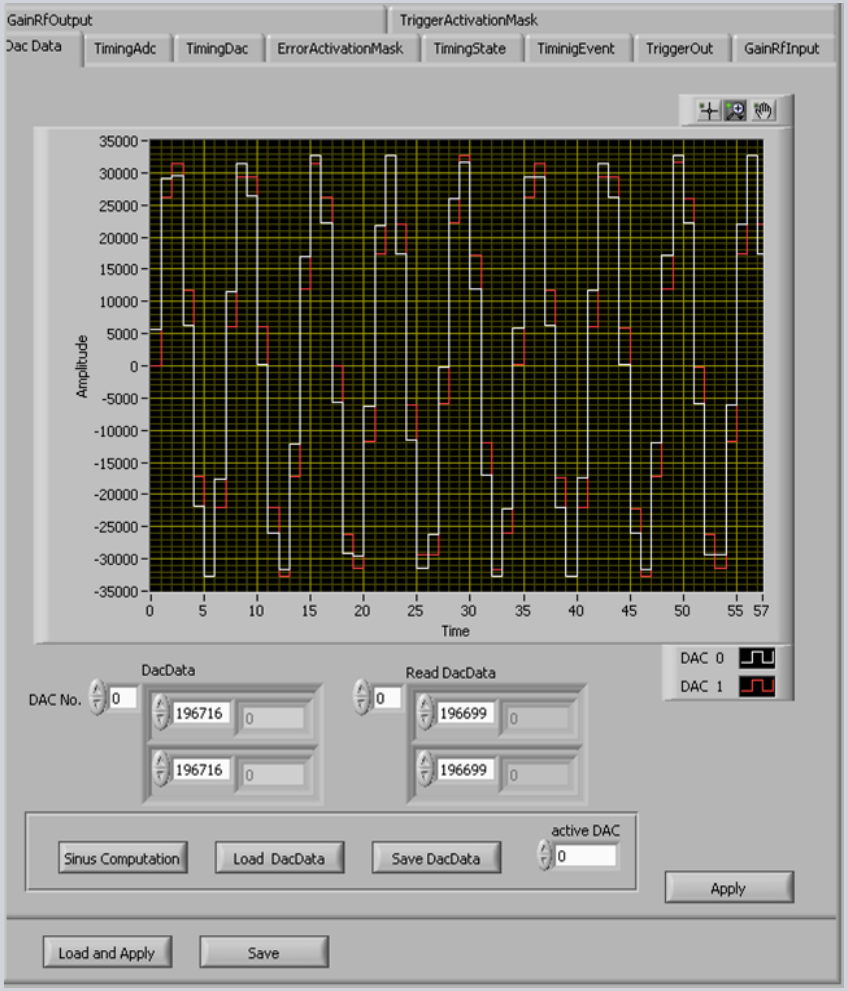
SIEMENS



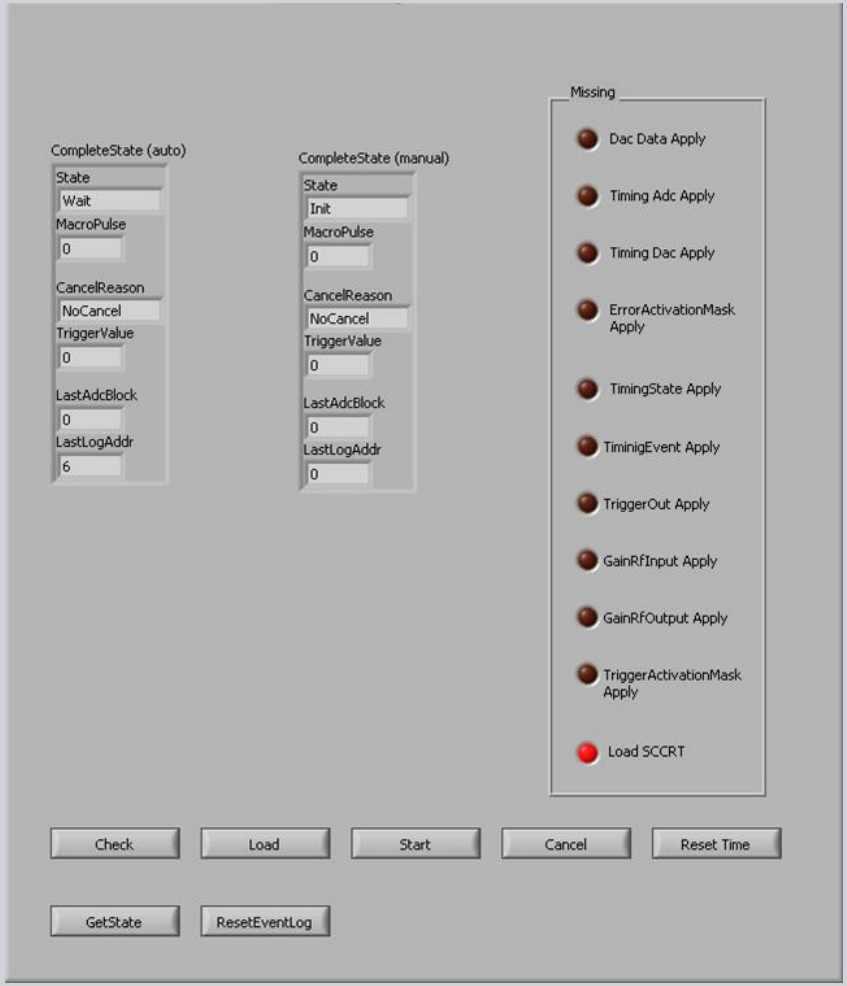


SCCRT first revision
Driver Functionality / LabVIEW Test GUI

SIEMENS



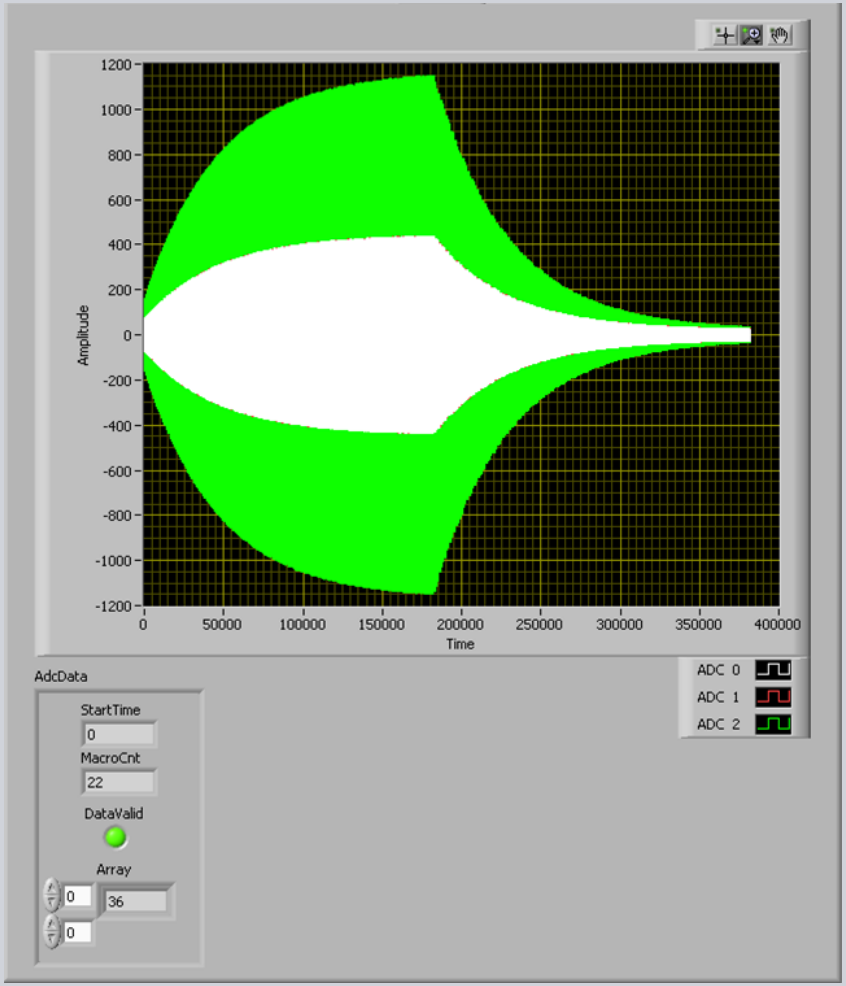
Configuration



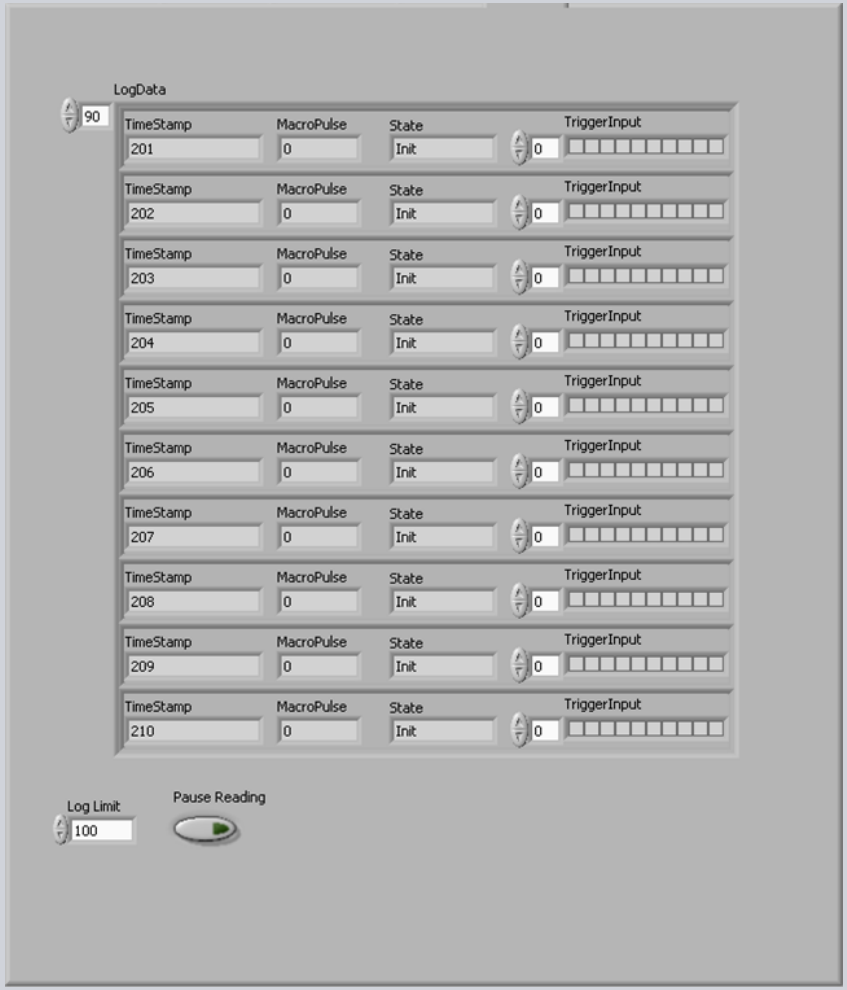
State Machine Control

SCCRT first revision
Driver Functionality and LabVIEW Test GUI

SIEMENS



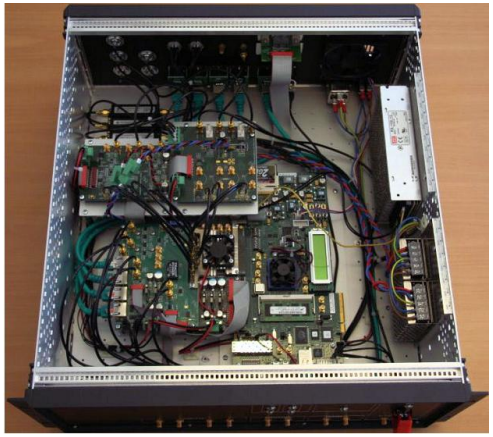
Asynchronous ADC data retrieval (test data by SCCRTUT)

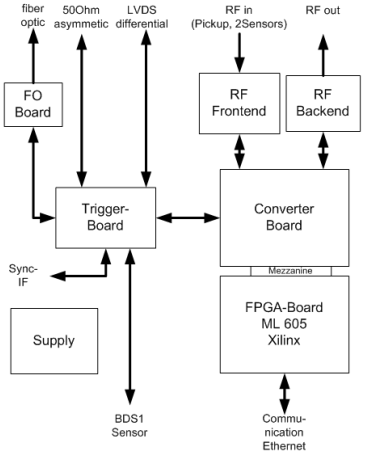


Asynchronous log data retrieval

SCCRT first revision
Board Layout and Device Photos

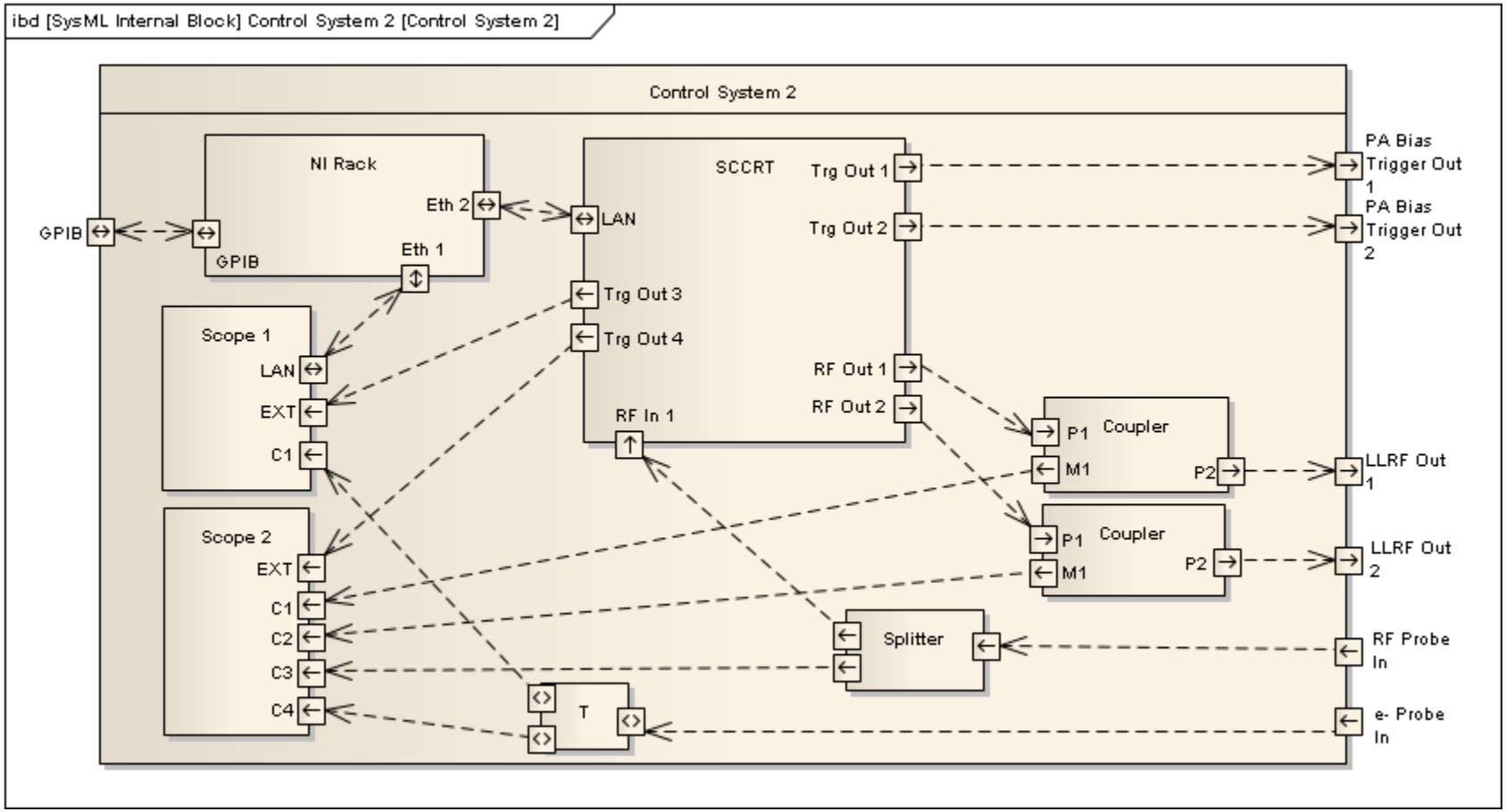
SIEMENS





SIEMENS

Control (Sub-)System with SCCRT



SIEMENS

Results

System commissioning tests:

- 64 modules and 512 SiC Transistors
- control system for power injection tests
- 150MHz
- U_{DS} = 160V
- Cavity GAP E-Field approx. 66MV/m
- Transmitted power approx. 120kW

SCCRT first revision:

- Hardware assembled
- LabVIEW driver and unit test code written
- Unit tests just started

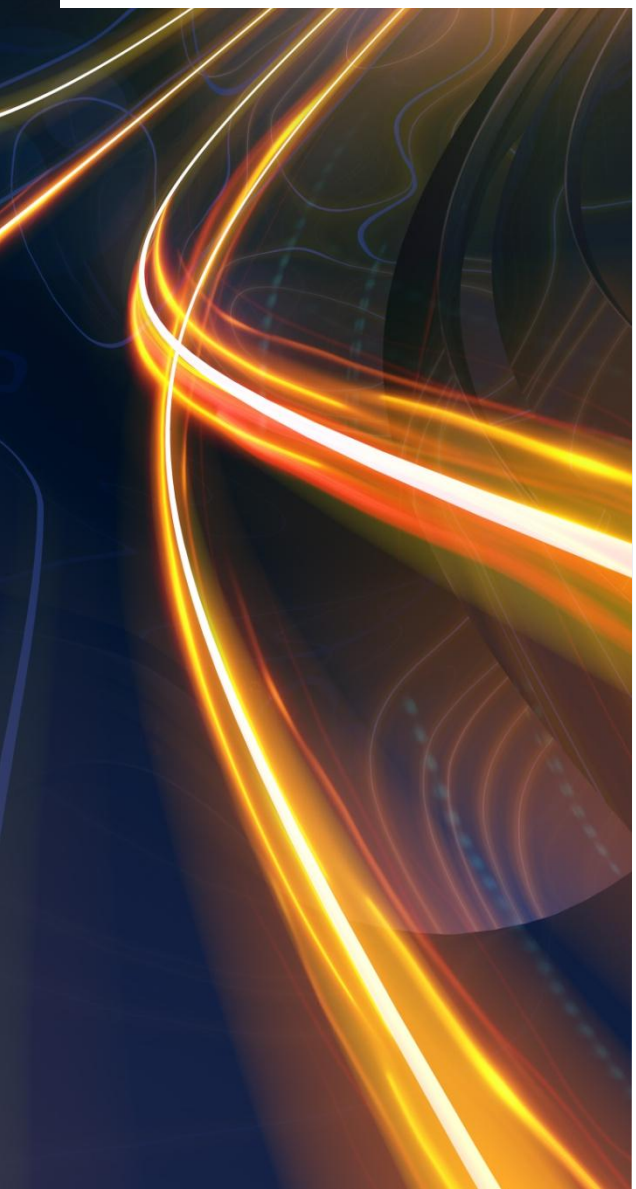
SIEMENS

Summary & Next Steps

- 64 Modules successfully integrated with control system
- First revision of SCCRT designed and built
- Taking SCCRT into operation has been started

- Next steps:
  - Digital control system:
    - Integration
    - Test outphasing approach
    - System identification
    - Reprogram FPGA (closed loop with PI regulator)
  - Power injection tests with higher module supply voltages

Thank you for your attention!



Thomas Kluge

Siemens AG

CT T P-HTC

Mozartstr. 57

91052 Erlangen

Germany

Phone: +49 (9131) 7-25435

Fax: +49 (9131) 7-26748

E-mail: thomas.kluge@siemens.com