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Development of a 10-bit 500 Msample/sec Waveform Digitizer

Outline:

- Overview & History
- Objectives
- Technical Progress
- Future Potential

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File: LeCroy CRADA

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Waveform Digitizer: Overview

"An Oscilloscope on a chip" A simple, robust, low-cost device to sample fast analog signals and convert them into digital data.

The device is characterized by the following:

- Sampling rate.
  The number of digital samples per second.

- Dynamic range/effective bits.
  The number of bits per sample.

- Input bandwidth.
  The speed of the signal that can be captured.
  Note that a mathematical theorem limits the bandwidth to less than half the sampling speed.

- Depth of Memory.
  The length of time samples can be stored prior to readout

- Readout speed.
  The length of time for the acquisition of digitized samples into standardized format.

- Cost.

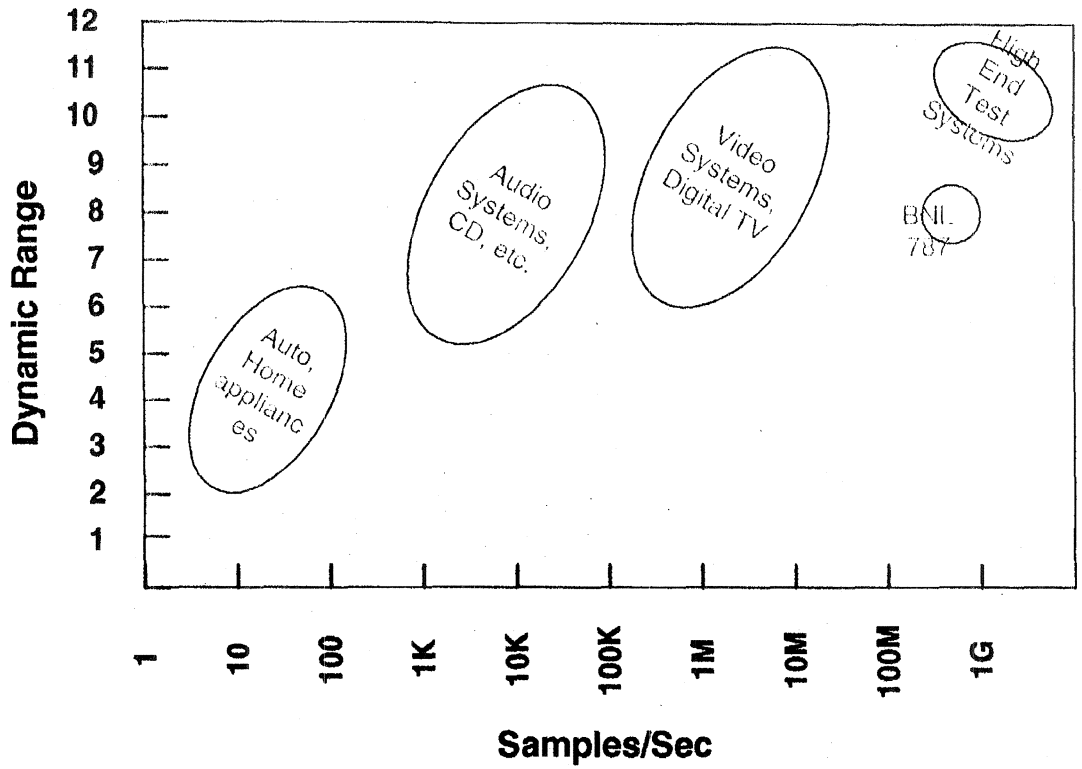


Figure 1 Performance of current Digital to Analog systems.

Funding

DOE (BNL)

	3/95-2/96		3/96-2/97	
	BNL CRADA	BNL non-CRADA	BNL CRARA	BNL non-CRADA
Manpower	237,022	0	248,873	0
Software	26,074	0	0	12,000
Parts	8,148	0	22,861	15,000
Total	271,244	0	271,734	27,000

Industry (LeCroy)

ADC design	207,000
Memory design	253,000
System design	21,000
Total	481,000

Project Summary

- Approved in late 1994, funded in March 1995.
- Goal is to utilize existing LeCroy Front End developments and BNL previous efforts to:
    - Extend the dynamic range from 8 to 9-10 bits.
    - Extend the depth of memory.
    - Lower the cost.
    - Increase availability to general research and industrial community.

Subsystem	Responsibility
Analog Front End (S/H) IC MFE415 & MSH417	LeCroy
ADC IC MAD422	LeCroy
Memory IC MEM424	LeCroy
Integration of front end and extension to 9-10 bits (MCM) (BNL-LRS 1)	BNL (Stony Brook)
Fast readout controller (BNL-LRS 2)	BNL
Bus interface logic	BNL
System Integration	BNL

Why BNL, Stony Brook and LeCroy?

- Long standing interest in this area.
- Proven accomplishments.
- Matched an Non-overlapping skills.

Examples

- BNL-E787 produced one of the largest waveform digitizers in existence.
    - 500 Msamples/sec at 8 bits dynamic range.
    - 2-400 μsec memory.
    - Fast readout (50 Mb/sec).
    - Zero suppression at write time.
    - 500 Channels.
    - In operation since 1988.
- LeCroy is one of the largest producers of high performance test systems.
    - Gsample/sec digital oscilloscopes.
    - Innovative Front End IC design.

Benefits and relevance to DOE mission

- Advances in this area of instrumentation are of critical importance to many areas of applied and basic research.
    - Detector instrumentation (the majority of US high energy physics research is funded by DOE).
    - Accelerator instrumentation (All US accelerators are funded entirely by DOE).
    - Test systems (relevant to DOE's mission in energy, environmental and health areas).
- Existing laboratory expertise and developments are made available to US industry.
    - First generation of devices developed for specific research purposes withDOE's support in 1988.
    - Leveraging of existing infrastructure allows for an efficient transfer to industry.

There is strong interest from both research and industrial community in this development.

Partial List of Expressed Interest (Customers?).

- High Energy/Nuclear Physics
    - g-2 Experiment at BNL.
    - Rare Kaon Experiments at BNL.
    - RHIC Beam Instrumentation Group.
- Industry (ref. LeCroy)

At least one previous generation of E787 development has been licensed to outside industry (SandersAssoc, Lockheed Corp.).

Technical Progress

- Sample & Hold, ADC, and Memory exist.
  - Sample & Hold capable of providing over 7 effective bits at 150 MHz input bandwidth (2GHz analog bandwidth).
  - ADC capable of 500 Msamples/sec and 8 bits of dynamic range.
  - Memory capable of 256 Kbytes and 2 nsec write speed.

- Integration MCM module has been designed and is under fabrication.
  - Use of a Multi-Chip Module (MCM) is essential to lower noise, increase packaging density and enhance reliability.
  - MCM is a single deliverable component that can be used by others.

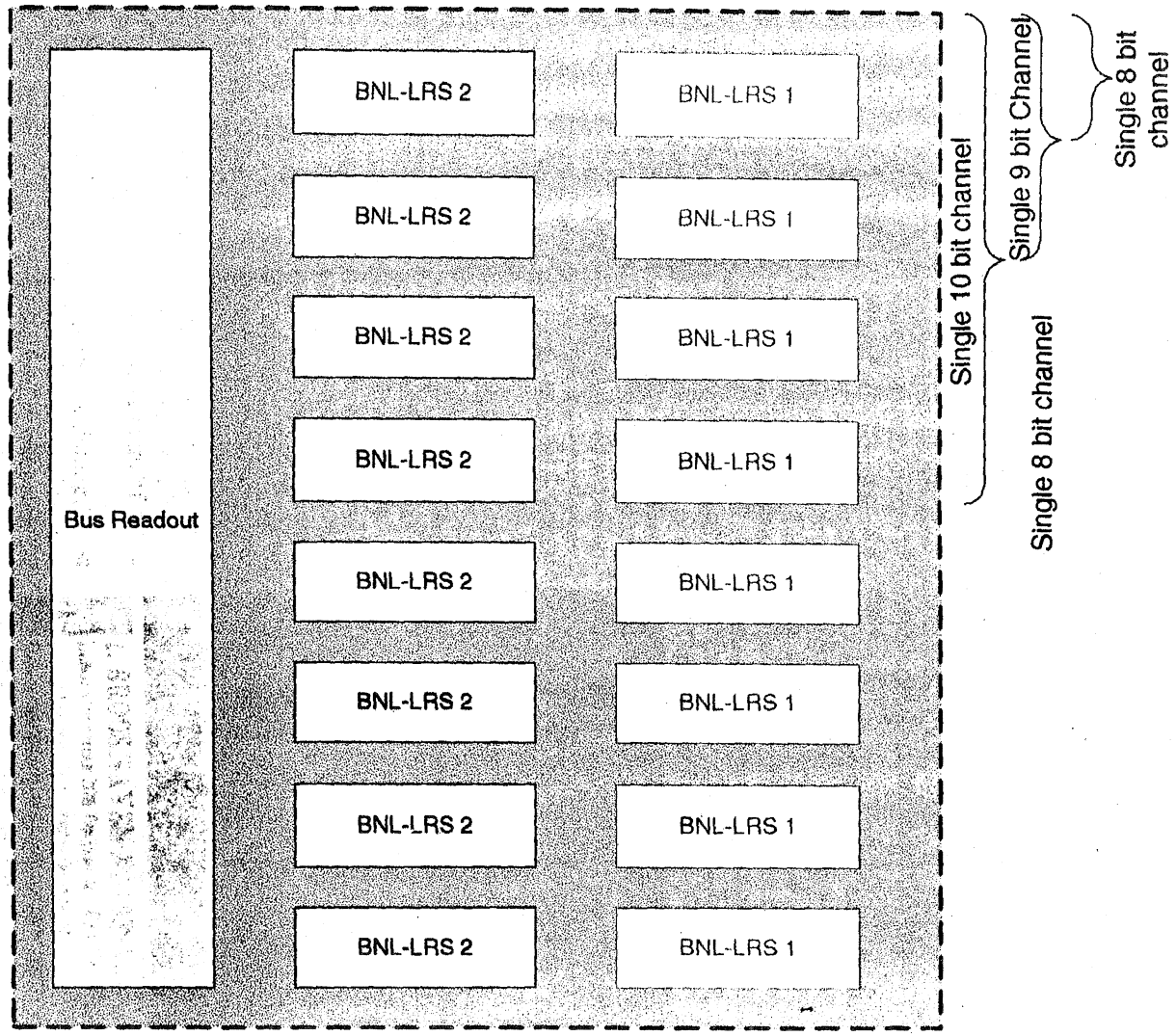
- Readout custom IC designed and tested.
  - Fast readout with "on the fly" zero subtraction is essential to allow use of the device at high rates.
  - Standardized output formats allow use in a wide variety of modules.
  - Designed using VHDL to allow utilization of the latest technology without extensive redesign.

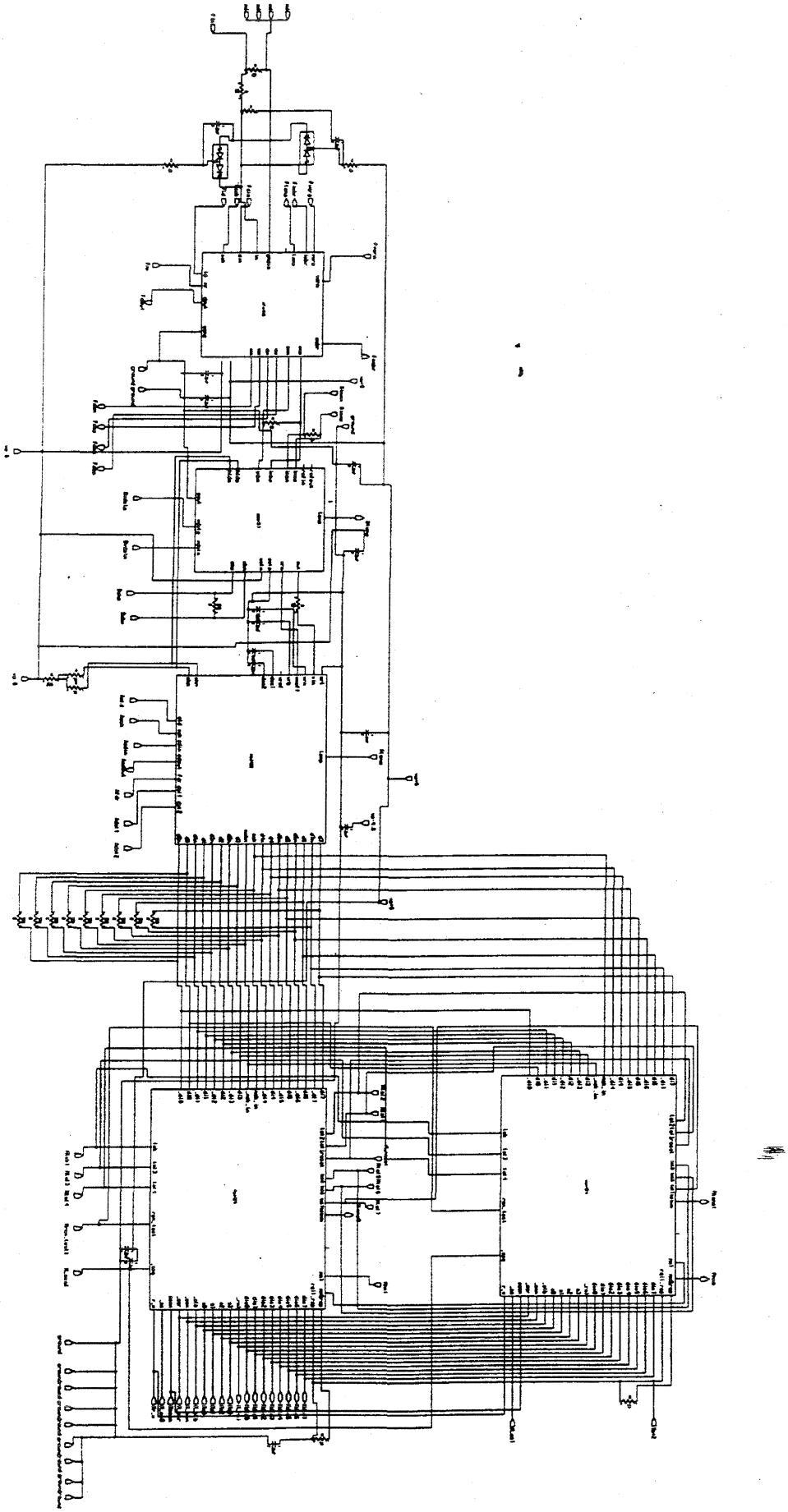
- Board level integration has started.

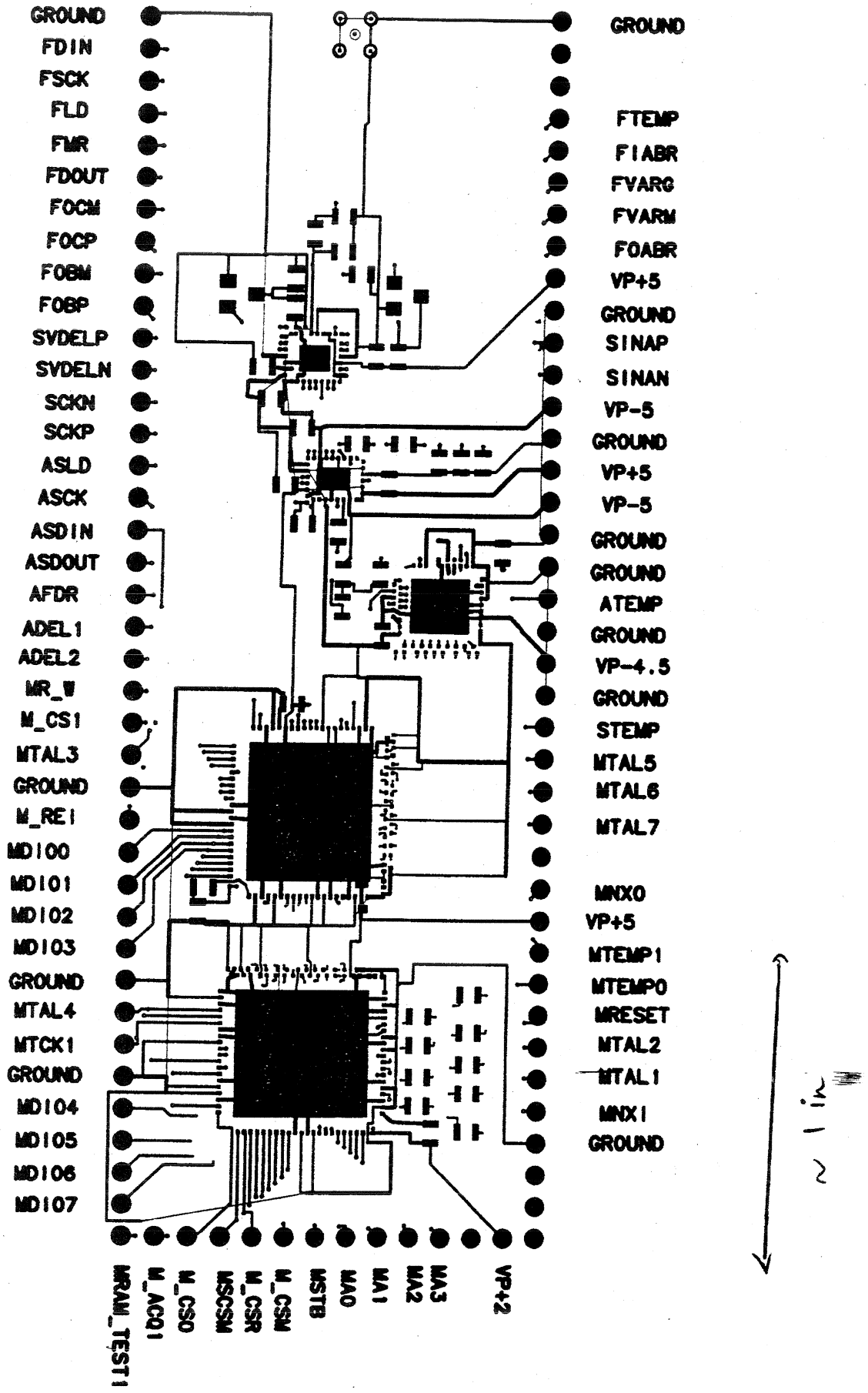
Specification of Waveform Digitizer

8 Channels in a single module capable of operating as 8 8-bits, 4 9-bits or 2 10-bits ADC.

Sampling Speed	> 500 Msamples/sec
Input Bandwidth	150-200 MHz
Depth of Memory	256 μsec
Readout Speed	40 nsec per non-zero sample
Zero suppression	At read, with pre and post sampling
Bus interface standard	CAMAC, Fastbus, VME
Power	< 60 watt /module
Software Support	Standard PC and UNIX readout codes


Bus Readout
BNL-LRS 2
BNL-LRS 1
BNL-LRS 2
BNL-LRS 1
BNL-LRS 2
BNL-LRS 1
BNL-LRS 2
BNL-LRS 1
BNL-LRS 2
BNL-LRS 1
BNL-LRS 2
BNL-LRS 1
BNL-LRS 2
BNL-LRS 1
BNL-LRS 2
BNL-LRS 1
Single 10 bit channel
Single 9 bit Channel
Single 8 bit channel
Single 8 bit channel

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FDIN
FSCK
FLD
FMR
FDOUT
FOCM
FOCP
FOBM
FOBP
SVDELP
SVDELN
SCKN
SCKP
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ASCK
ASDIN
ASDOUT
AFDR
ADEL1
ADEL2
MR_W
M_CS1
MTAL3
GROUND
M_RE1
MDI00
MDI01
MDI02
MDI03
GROUND
MTAL4
MTCK1
GROUND
MDI04
MDI05
MDI06
MDI07
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M_ACQ1
M_CS0
MSCSM
M_CSR
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MSTB
MA0
MA1
MA2
MA3
VP+2
GROUND
FTEMP
FIABR
FVARG
FVARM
FOABR
VP+5
GROUND
SINAP
SINAN
VP-5
GROUND
VP+5
VP-5
GROUND
GROUND
ATEMP
GROUND
VP-4.5
GROUND
STEMP
MTAL5
MTAL6
MTAL7
MNX0
VP+5
MTEMP1
MTEMP0
MRESET
MTAL2
MTAL1
MNX1
GROUND