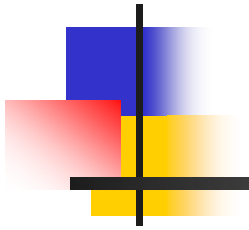

Magnet Safety System

Why?

How?

What?

MSS

- Protects all LHC experiment magnets
- ALICE
  - Warm Dipole and Solenoid magnets
- ATLAS
  - Cold magnets – Barrel Toroid, End-caps, Central Solenoid
- CMS
  - Cold magnet – Solenoid in 5 yokes
- LHCb
  - Warm Dipole

MSS

- Stored energy
  - MSS must protect the magnets against its own stored energy
- Quench
  - MSS must protect the magnets against quenches (ATLAS and CMS)

MSS

- Stored energy
  - Energy in magnetic field:
  - $E = \frac{1}{2} \times L \times I^2$

MSS

- Stored energy
  - Energy in magnetic field:
  - $E = \frac{1}{2} \times L \times I^2$
    - ALICE Dipole: 6 kA, 1 H => 18 MJ

MSS

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  - Energy in magnetic field:
  - $E = \frac{1}{2} \times L \times I^2$
    - ALICE Dipole: 6 kA, 1 H => 18 MJ
    - ATLAS: 20.5 kA, ~7.3 H => 1.6 GJ

MSS

- Stored energy
  - Energy in magnetic field:
  - $E = \frac{1}{2} \times L \times I^2$
    - ALICE Dipole: 6 kA, 1 H => 18 MJ
    - ATLAS: 20.5 kA, ~7.3 H => 1.6 GJ
    - CMS: 20 kA, ~13 H => 2.6 GJ!

    => Melts 18 tons of gold

MSS

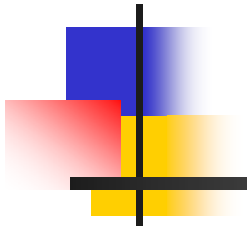
- Stored energy
  - Energy in magnetic field:
  - $E = \frac{1}{2} \times L \times I^2$
    - ALICE Dipole: 6 kA, 1 H => 18 MJ
    - ATLAS: 20.5 kA, ~7.3 H => 1.6 GJ
    - CMS: 20 kA, ~ 13 H => 2.6 GJ!

    => Melts 18 tons of gold

    => ~ 650 kilo of TNT

MSS

- Quench
  - Training quenches
    - Magnet system settling
  - Spurious quenches
    - < 1 mJ to quench
  - Alarm level: 1 volt/1 second => 20 kW



Magnet Safety System

Why?

How?

What?

MSS

- The purpose of the MSS is to detect anomalies endangering the safety of the magnet and to take appropriate action in order to bring the magnet into a safe state.

  - Maximum availability/reliability
  - Dedicated sensors
  - Multiple detection techniques/Overlapping sensors
  - Redundancy
  - Galvanic Isolation
  - Fail-safe operation
  - Common Hard-ware – Software (!)

  - ALL problems must be detected!
  - NO false problems may be detected!

MSS

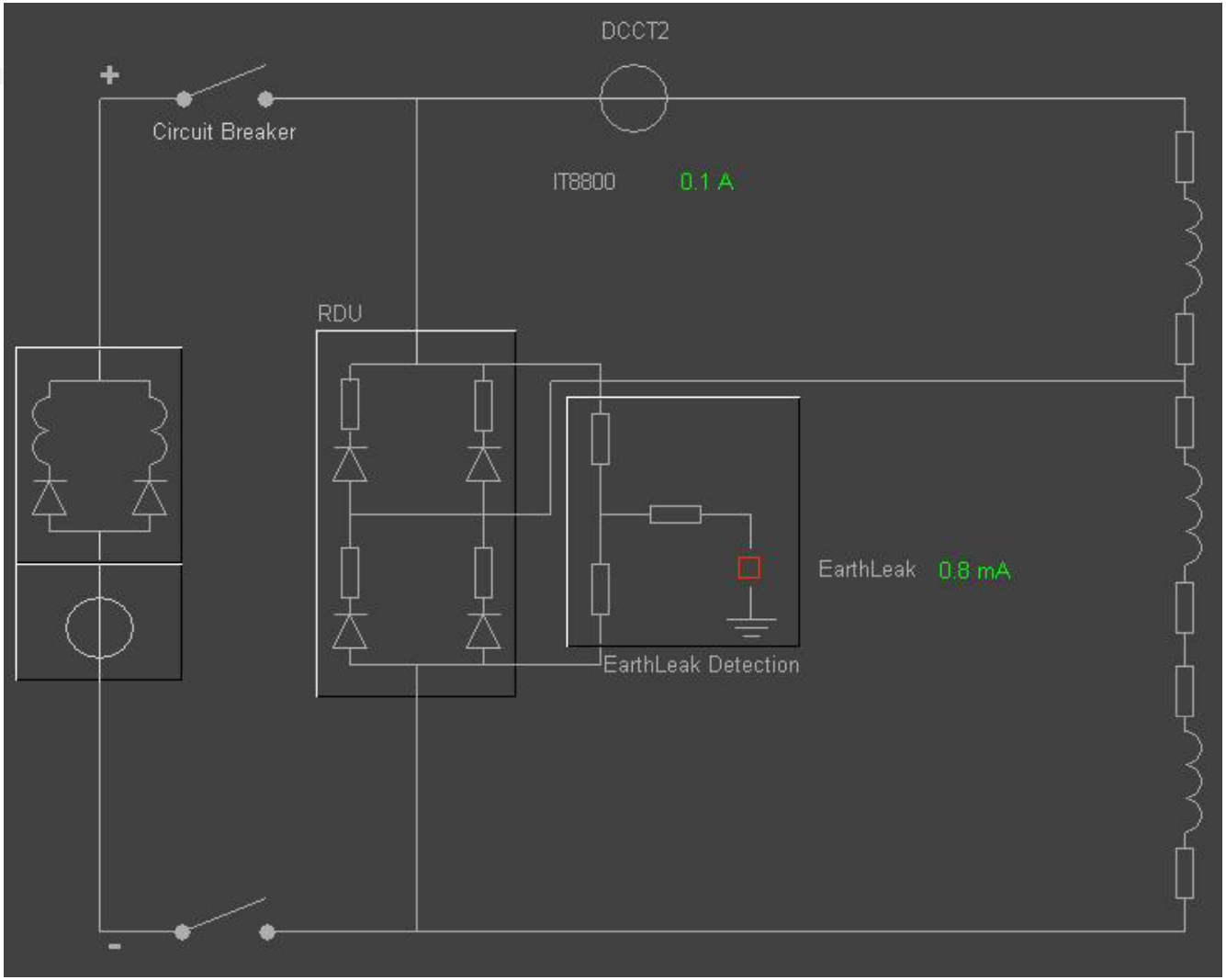
- Measurement methods:
  - Voltage?
  - Temperature?

MSS

- Voltage measurements?
  - Yes and no...
  - $V=-L*(dI/dt)$

MSS

ATLAS Electrical Circuit



MSS

- Voltage measurements
  - Yes and no
  - V=-L*(dI/dt)
  - Long ramp times
  - Noise?

MSS

- Voltage measurements
  - Yes and no
  - V=-L*(dI/dt)
  - Only for bus-bar protection (no inductive component)

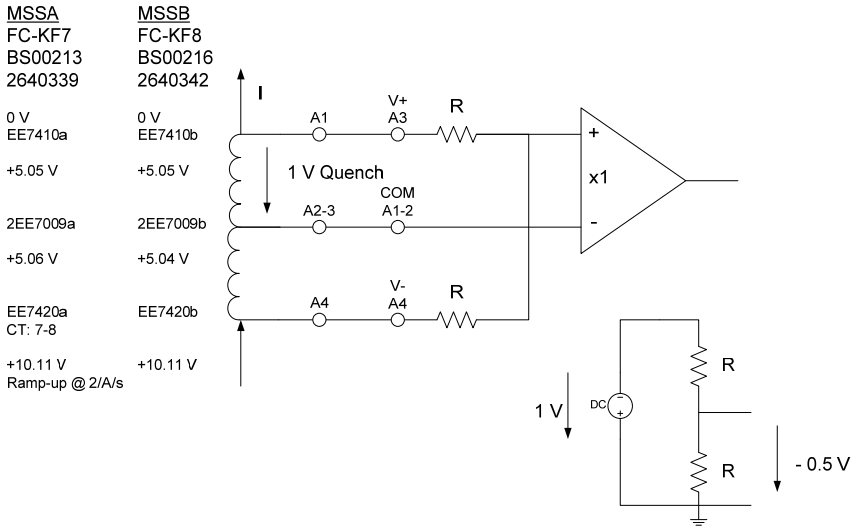
MSS

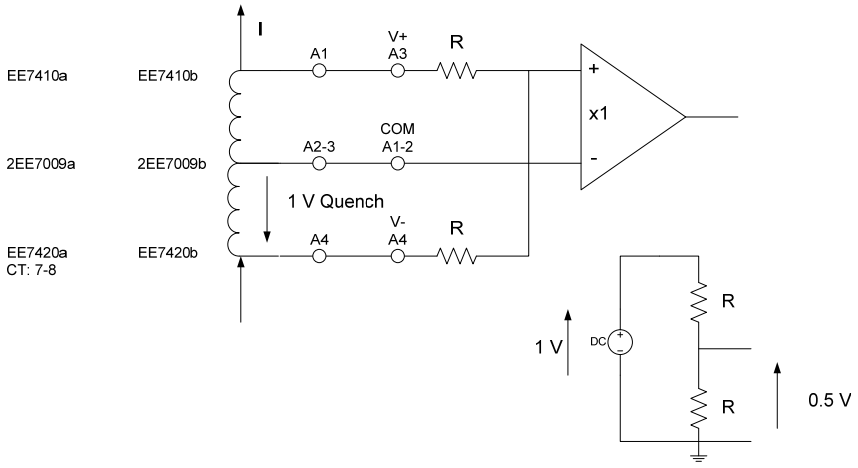
- Temperature measurements
  - Yes, but...
  - Many channels needed
    - CMS: 200 channels initially
    - ALICE: 168 channels
  - Mostly for bus-bar protection (CMS-ATLAS)
  - Main protection in ALICE and LHCb (Thermoswitches)

MSS

Bridge Measurements

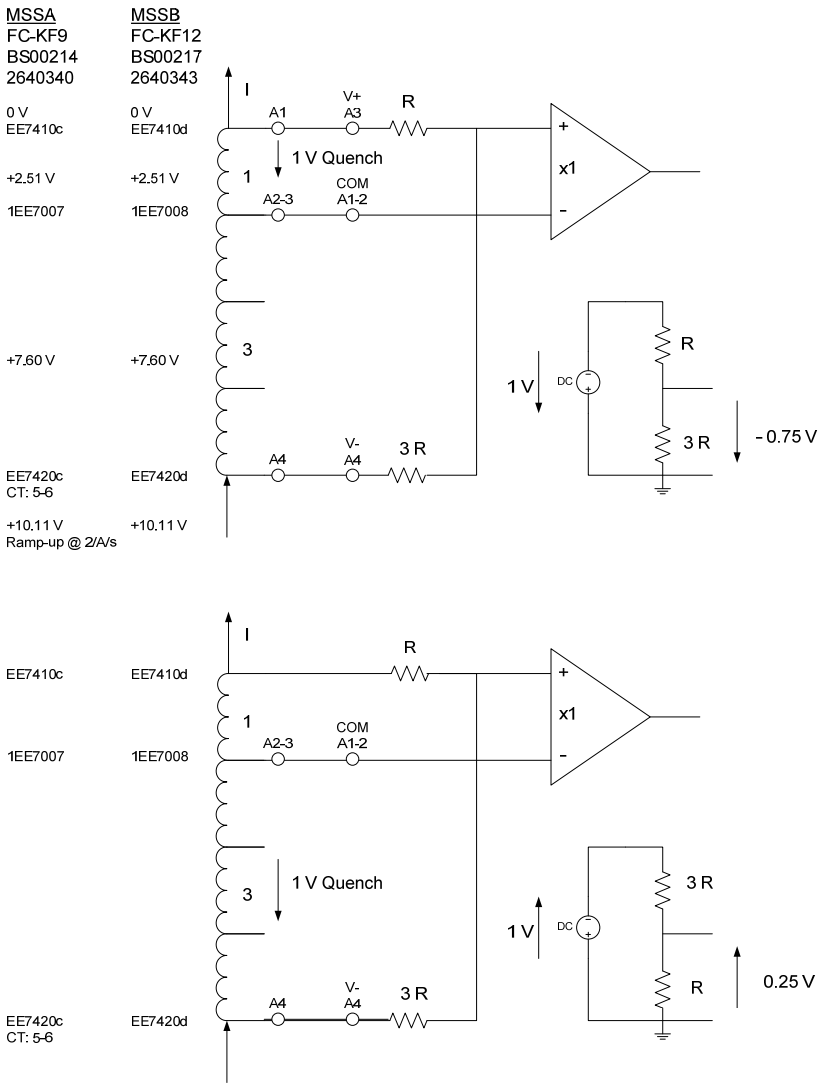
Used in:
ATLAS BT - ECT – CS
CMS



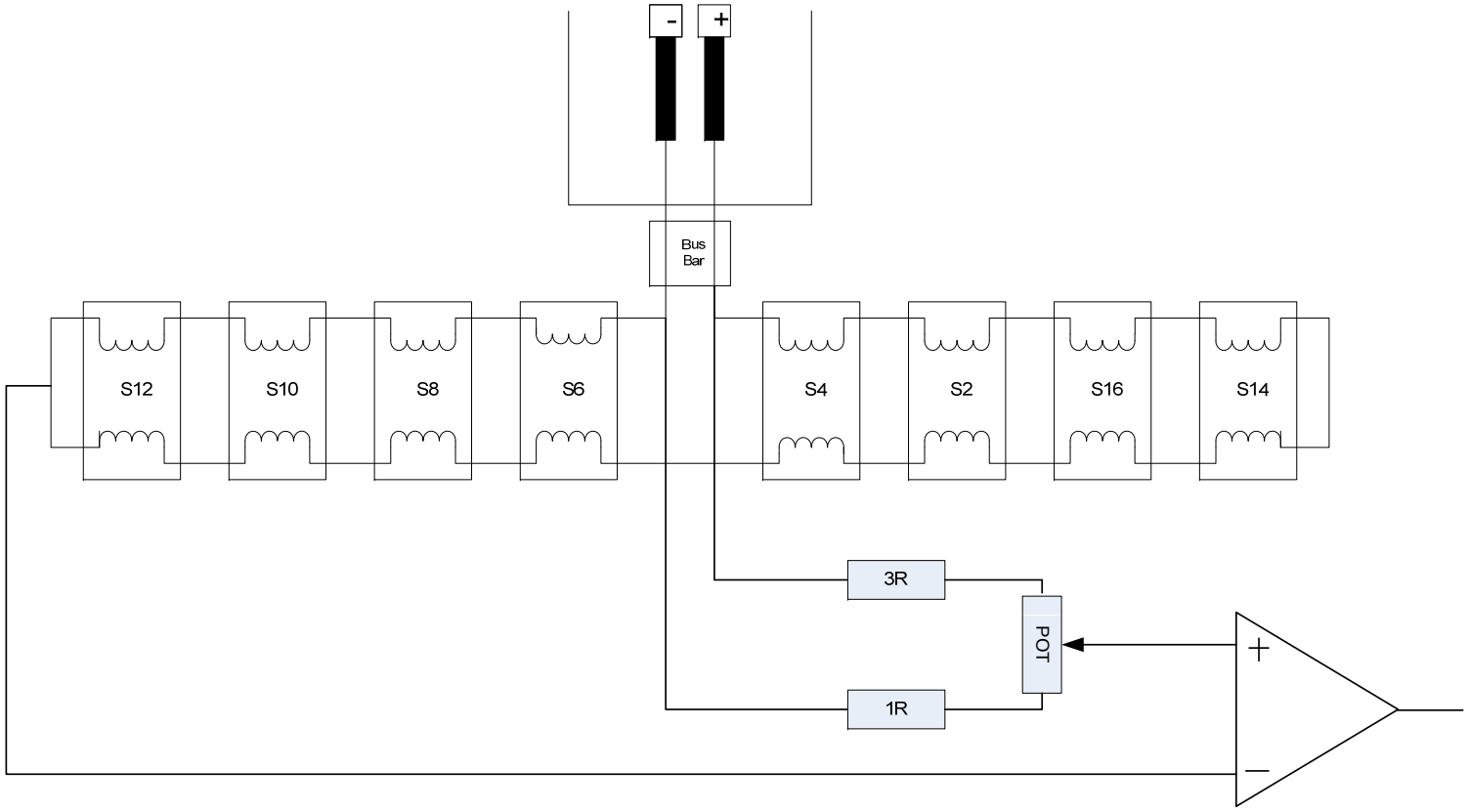


MSS

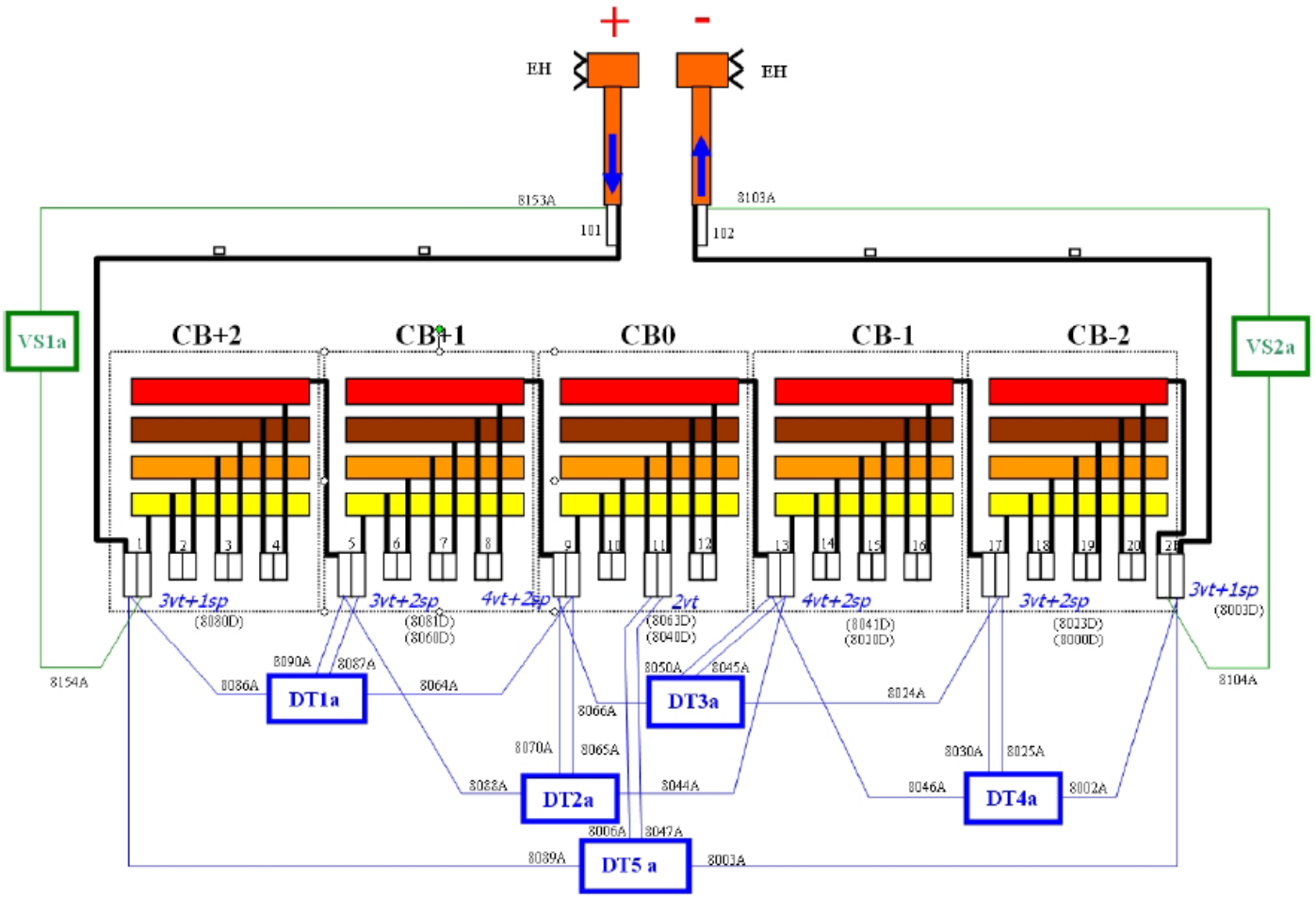
Bridge Measurements



MSS – ATLAS ¾ Bridge Connection



MSS – CMS Bridge Protection

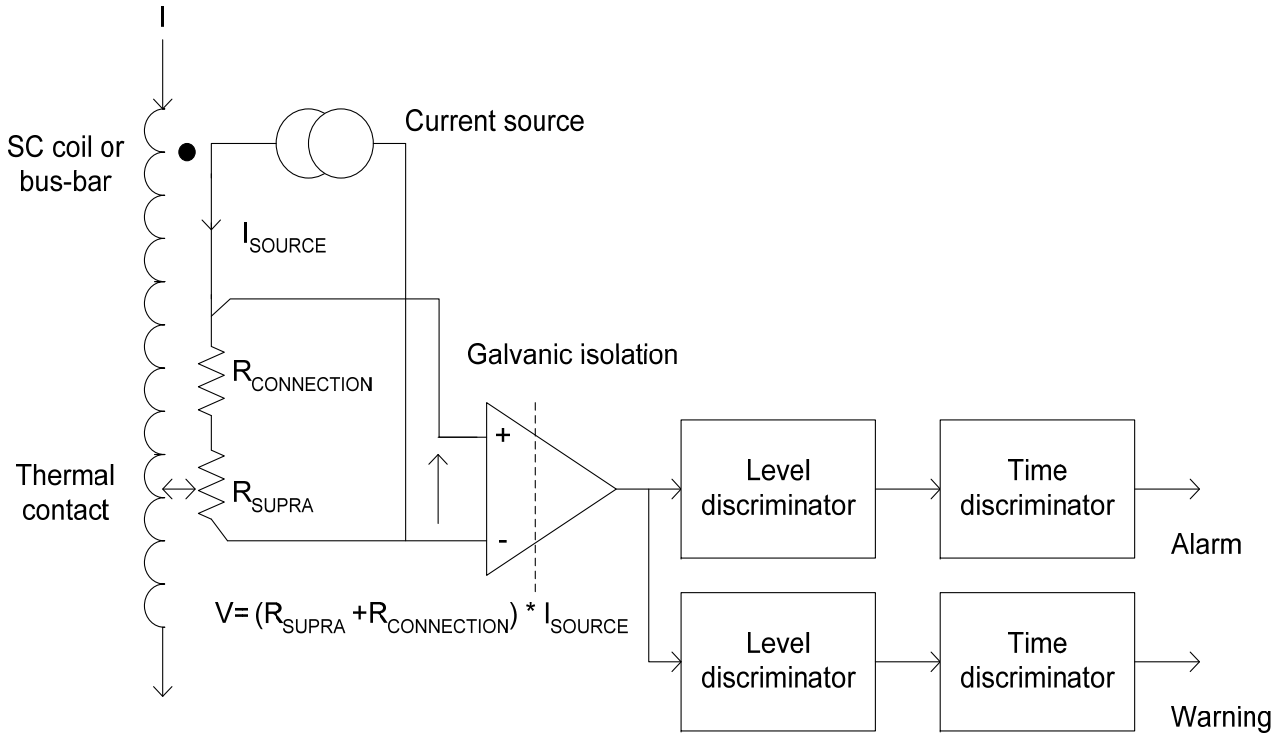


MSS

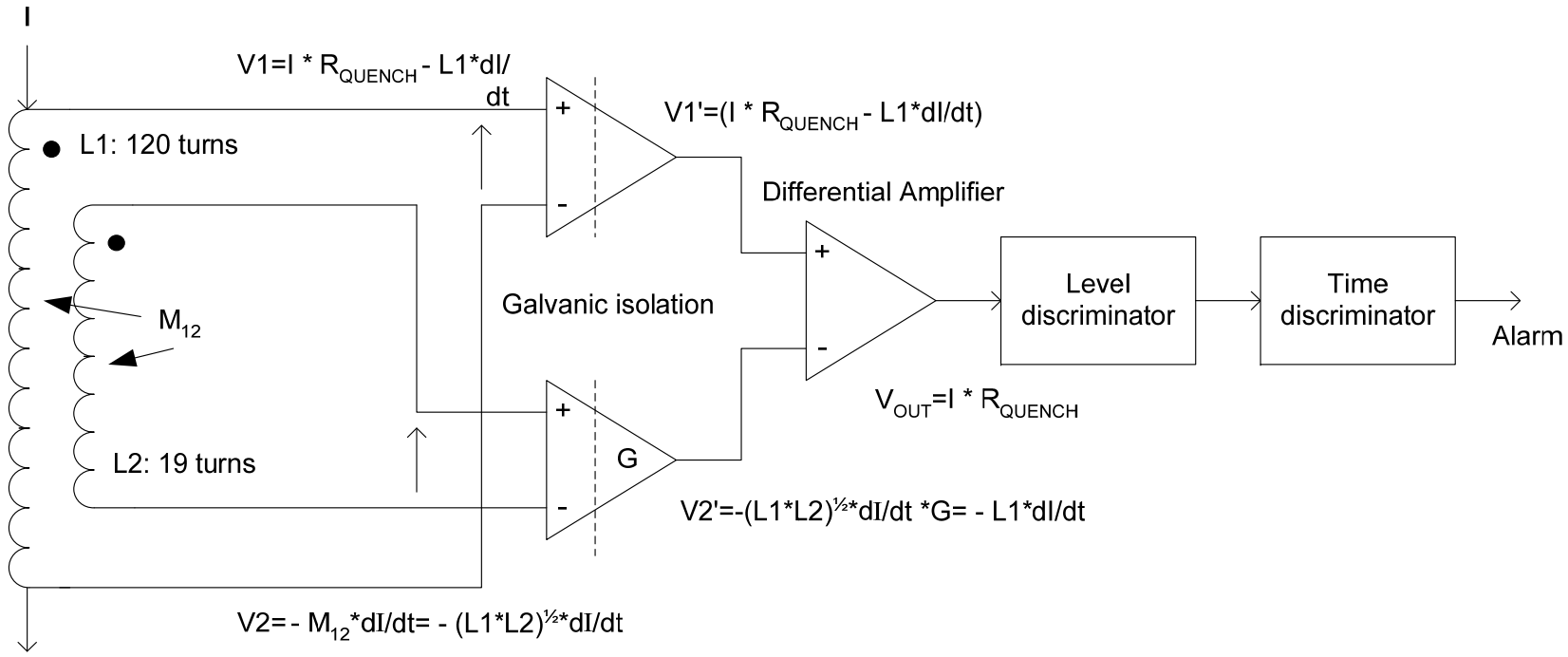
- Overlapping sensors?
- Multiple detection techniques?

MSS –Supra-Quench Detection (SQD)

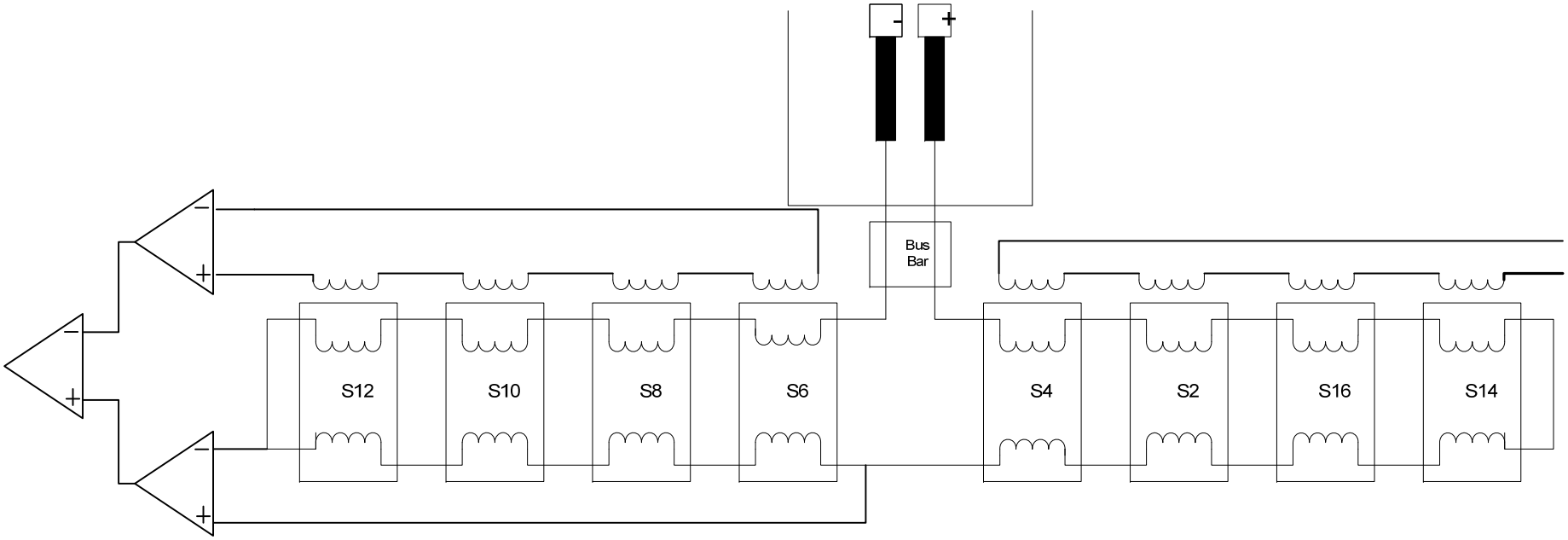
Used in ATLAS only



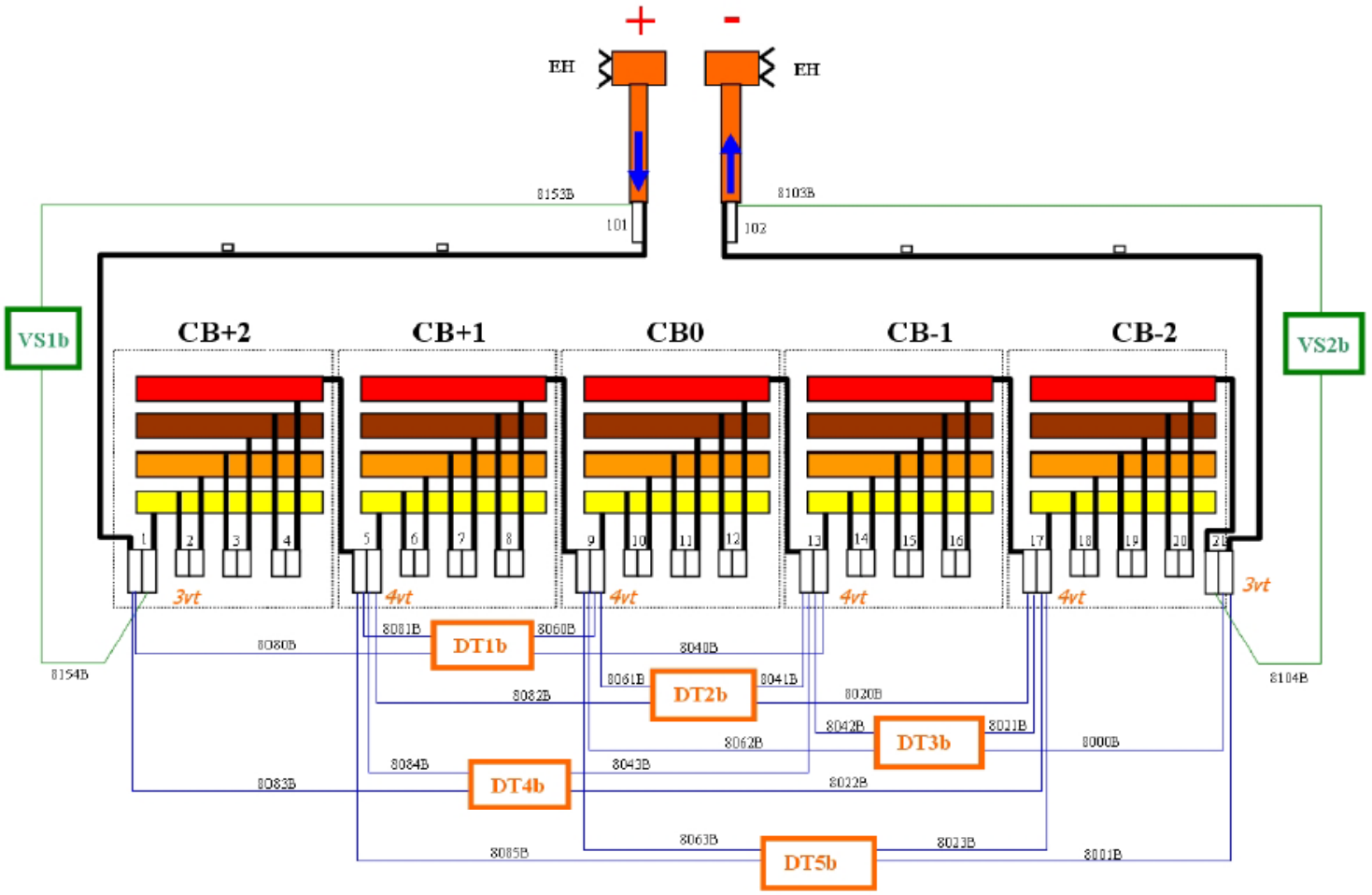
MSS – Differential Detection



MSS – ATLAS BT Differential Detection



MSS – CMS Differential Detection



MSS

- Problem detected! What now?

MSS

- Problem detected! What now?
  - ALICE Dipole and Solenoid
  - LHCb
    - Cut Power Converter
    - Diverse status signals

MSS

Slow Dumps:

- For all machine related signals (MCS, Cryo, Vacuum..)
- For minor magnet measurement signals (sensor faults..)
- Emergency Stop in local control room and racks
- Emergency Stop in ACR

Fast Dumps:

- For all serious magnet measurements
- Emergency Stop in local control room and racks
- Emergency Stop in ACR

Difference:

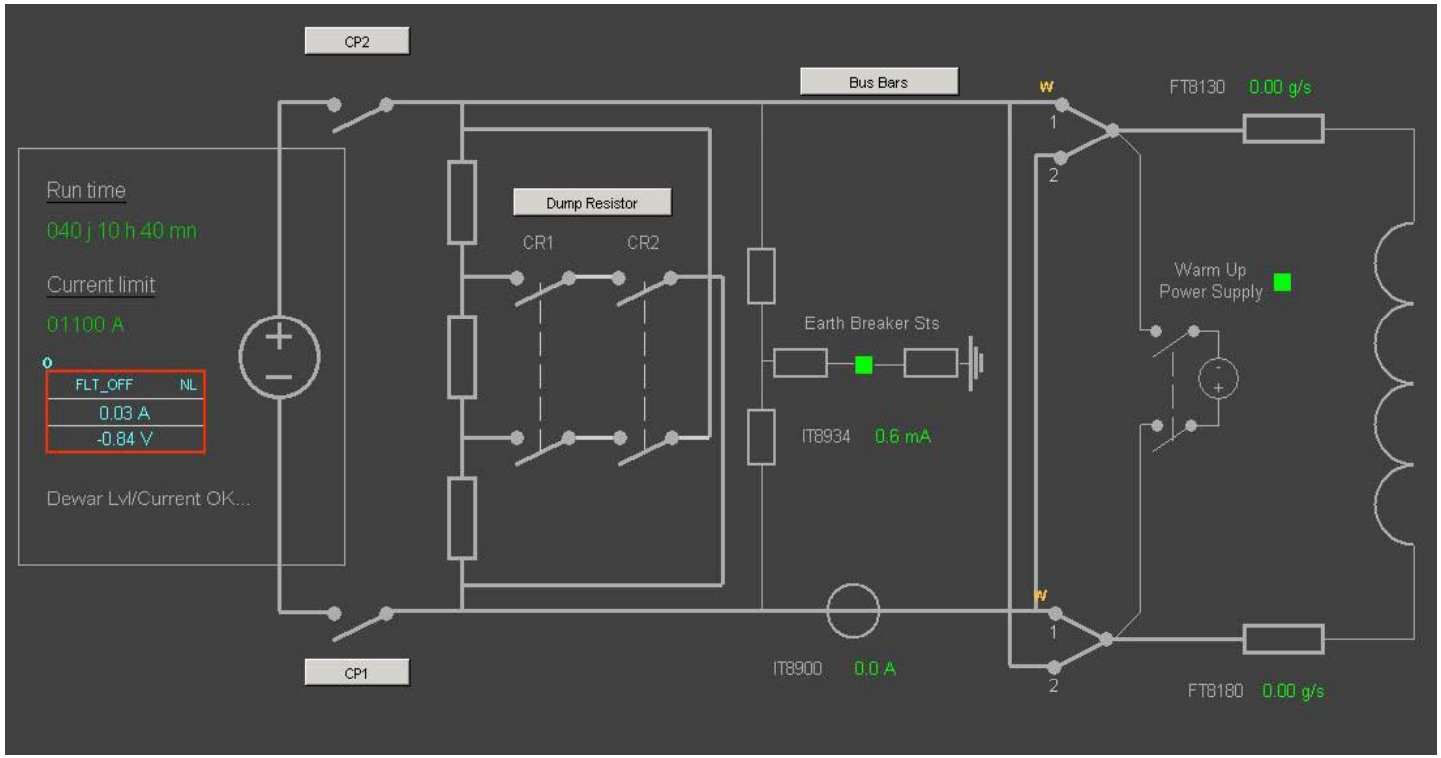
$\tau = L/R$

MSS

CMS Electrical Circuit

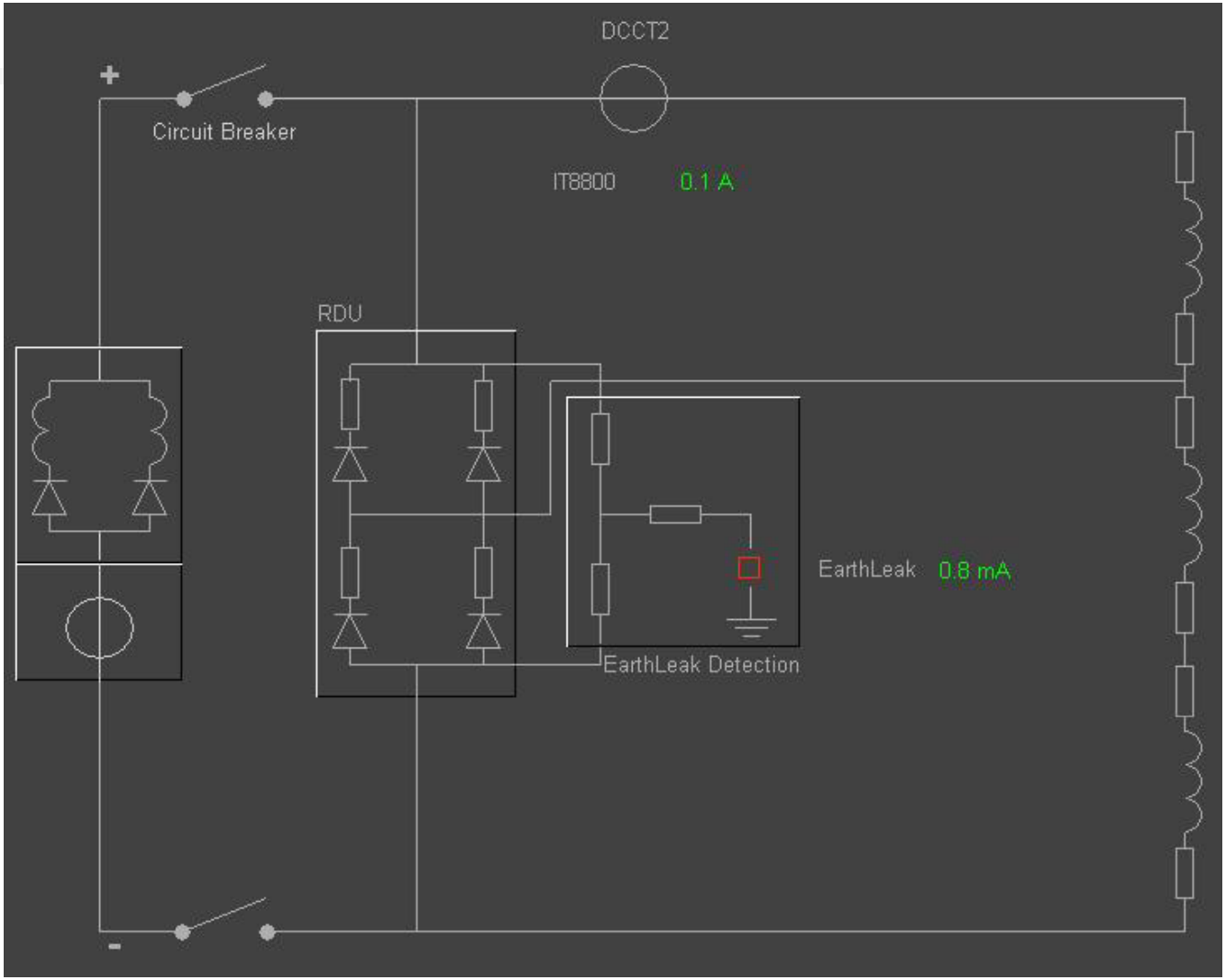
Operator

R_{SD}=2 mOhm
R_{FD}=30 mOhm
V_{FD}!



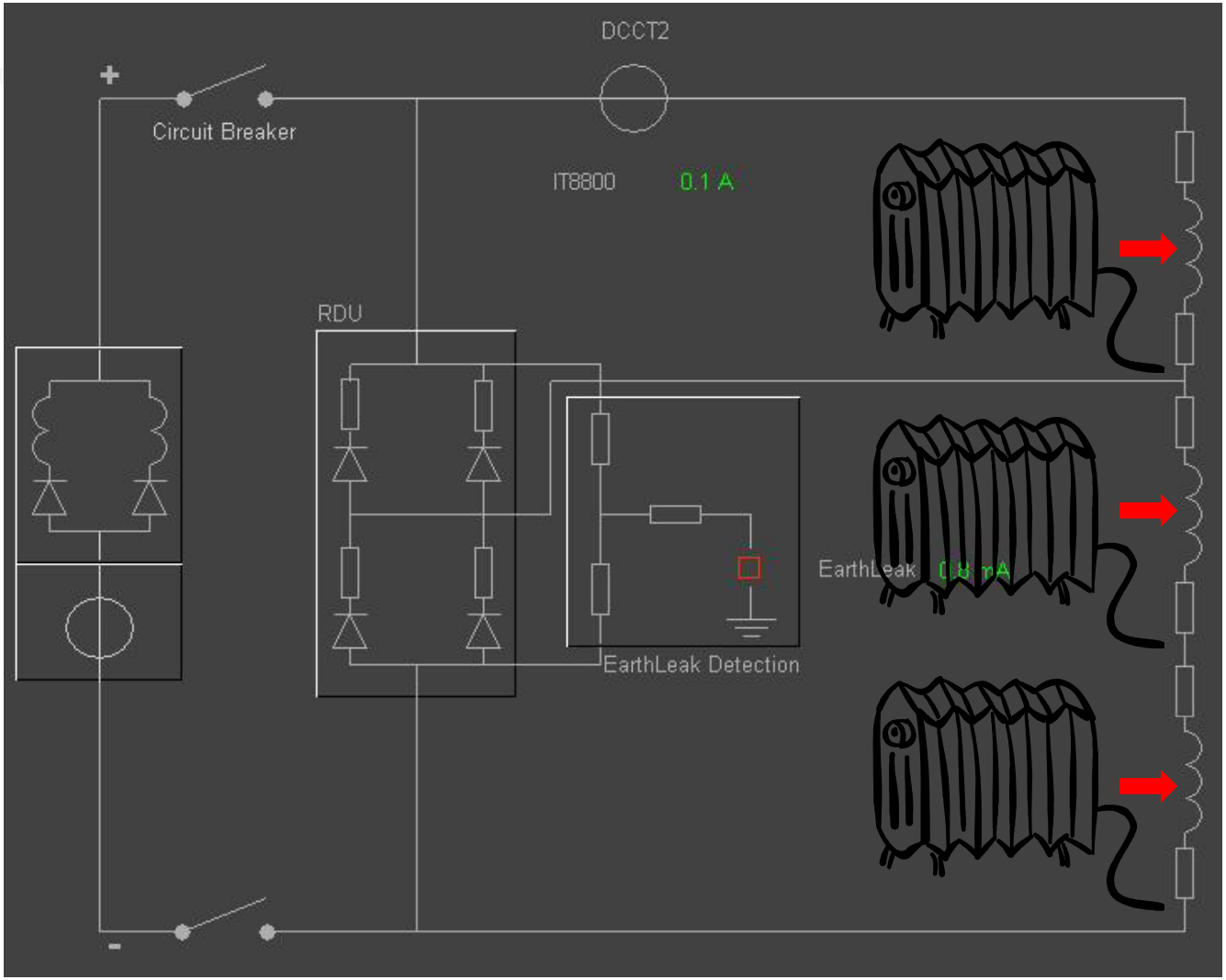
MSS

ATLAS Electrical Circuit



MSS

ATLAS
Electrical
Circuit

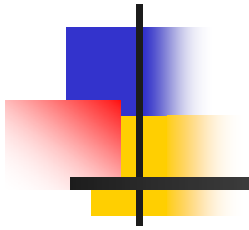


MSS

- Fast Dump
  - Then what...
  - Noise?

MSS

- Fast Dump
  - Then what...
  - Cryogenics recovery!
    - ATLAS 4-5 days
    - No false quench detection!
  - MDS analysis



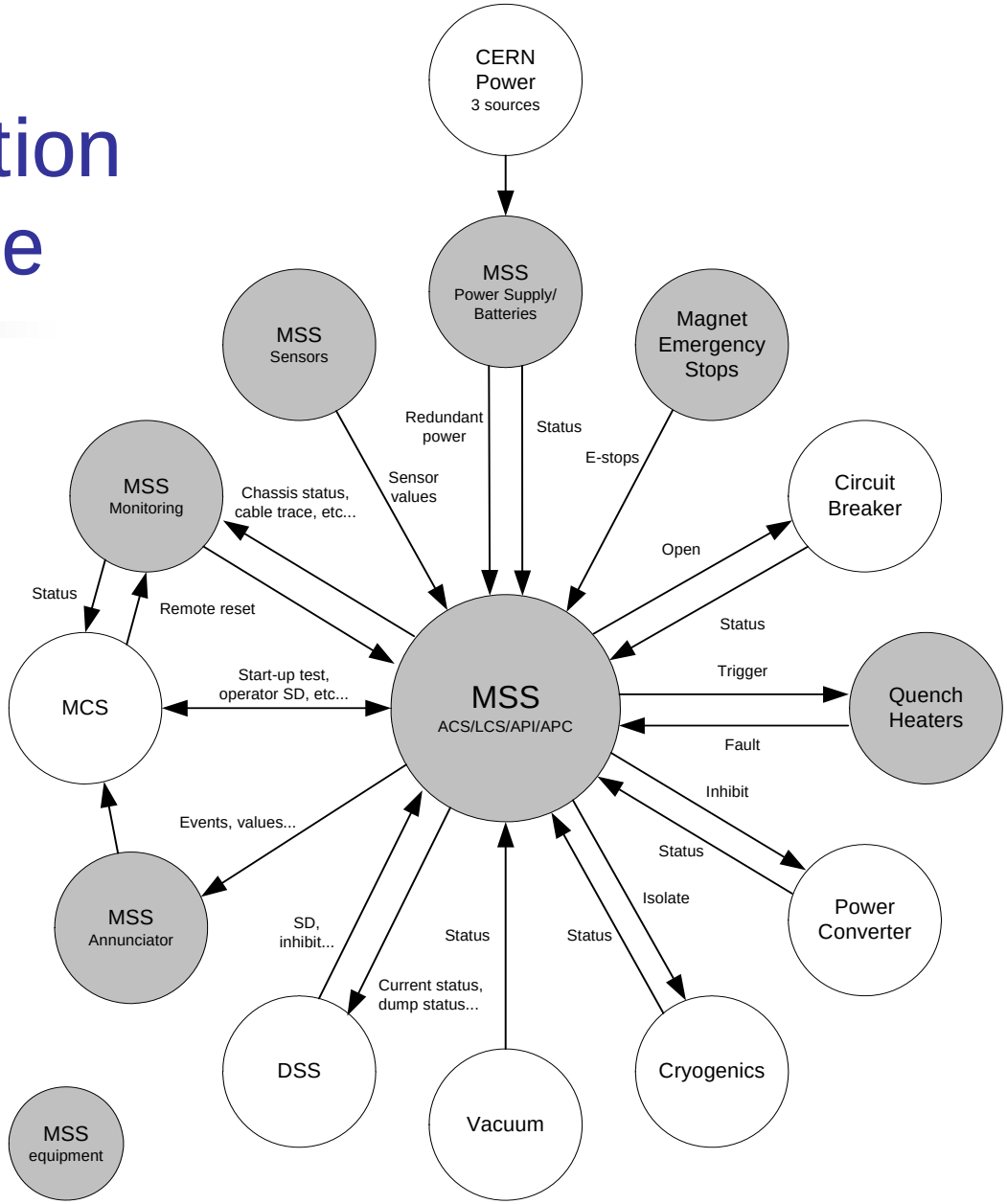
Magnet Safety System

Why?

How?

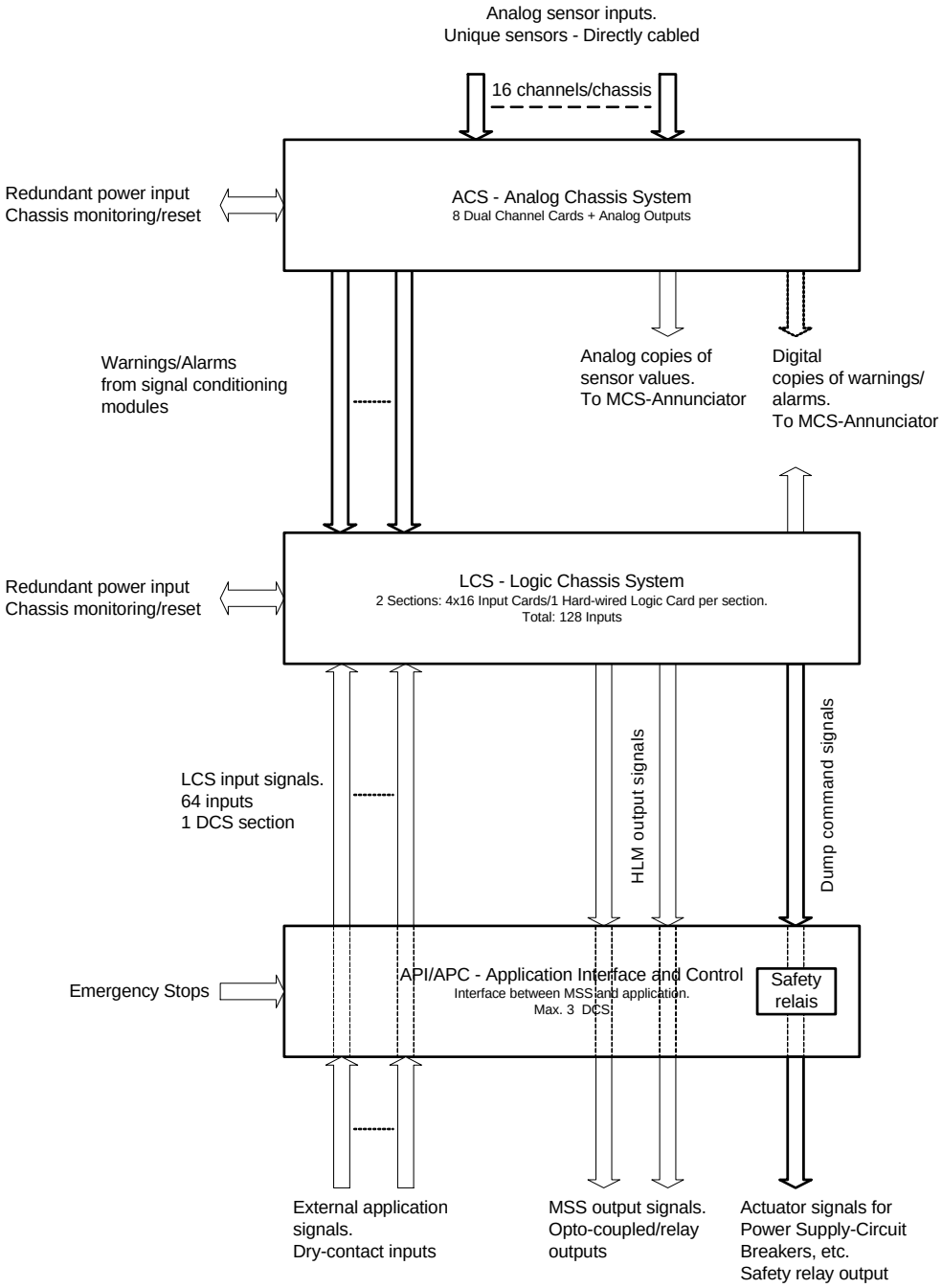
What?

Information Exchange



Block Diagram

ACS: Analog Chassis System
LCS: Logic Chassis System
APC: Application Control
API: Application Interface



Typical Rack

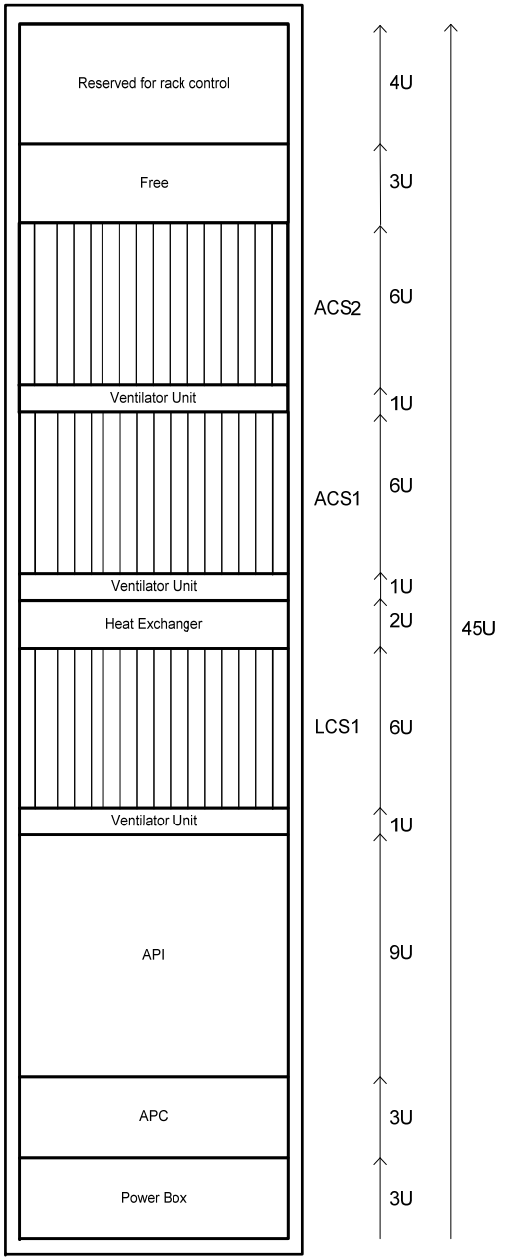
CM1A: DVM 1: DCCT voltage 1
CM1B: DVM 2: DCCT voltage 2
CM2A: DVM 3: Chimney voltage +
CM2B: DVM 4: Chimney voltage -
CM3A: DVM 5: Current lead voltage +
CM3B: DVM 6: Current lead voltage -
CM4A: Not used
CM4B: Not used

CM1A: DRM 1: Coil SQD
CM1B: Not used
CM2A: DRM 3: Chimney SQD 1
CM2B: DRM 4: Chimney SQD 2
CM3A: Not used
CM3B: Not used
CM4A: Not used
CM4B: Not used

CM6A: DBQD 1: Bridge quench detection 1-1/3
CM6B: DBQD 2: Bridge quench detection 2-1/2
CM7A: DBQD 3: Bridge quench detection 3-2/3
CM7B: DBQD 4: Not used
CM8A: Not used
CM8B: Not used
CM9A: Not used
CM9B: Not used

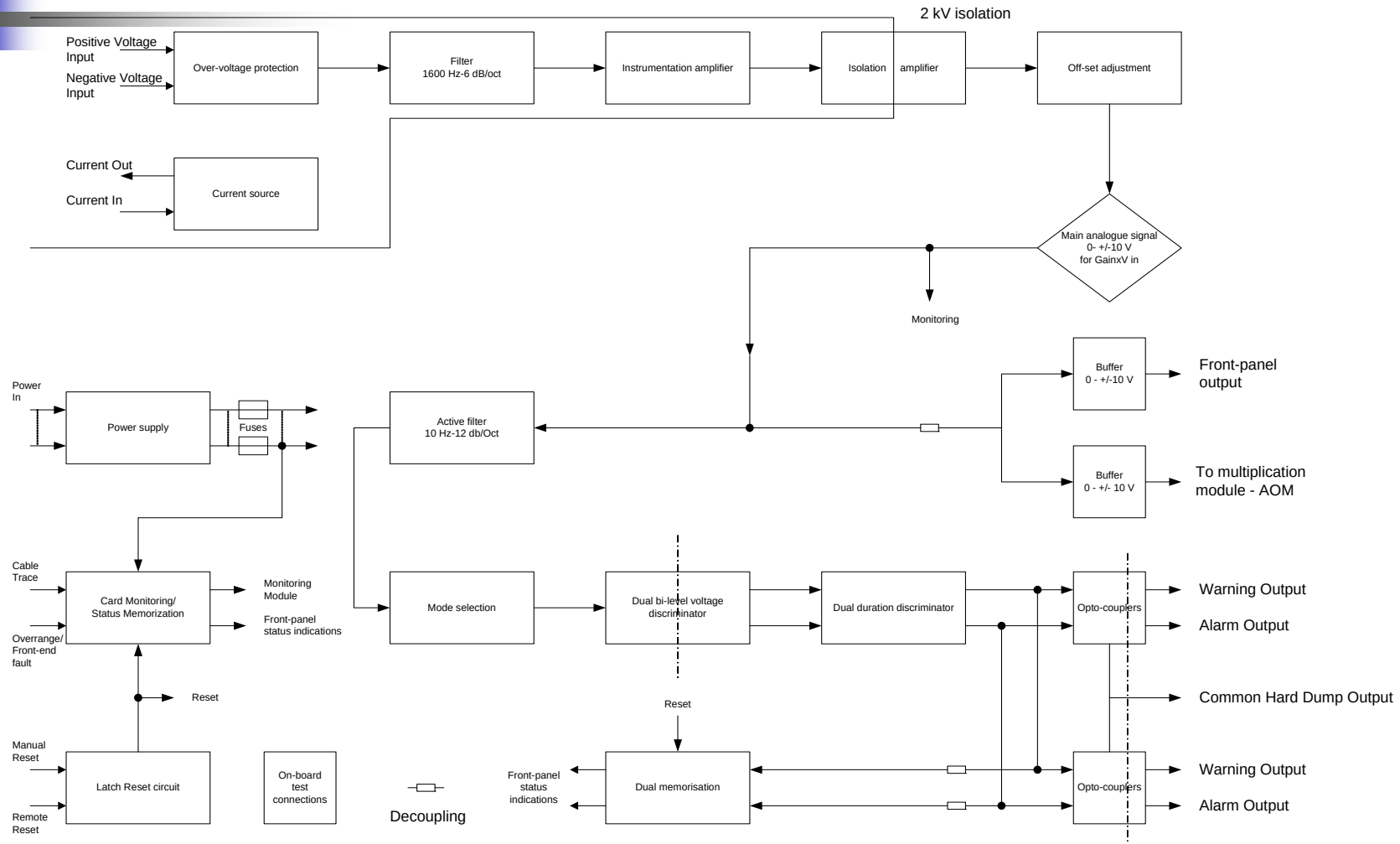
CM6A: DTM 1: Bulk-head temperature
CM6B: Not used
CM7A: DTM 3: Chimney temperature
CM7B: Not used
CM8A: DTM 5: Current lead temperature +
CM8B: DTM 6: Current lead temperature -
CM9A: DTM 7: Coil temperature 1
CM9B: DTM 8: Coil temperature 2

DIM1-2: External signals
DIM3-4: External signals
DIM6-7: Warnings/Alarms from ACS1
DIM8-9: Warnings/Alarms from ACS2
HLM5: External signal treatment
HLM6: ACS1 + ACS2



MSS

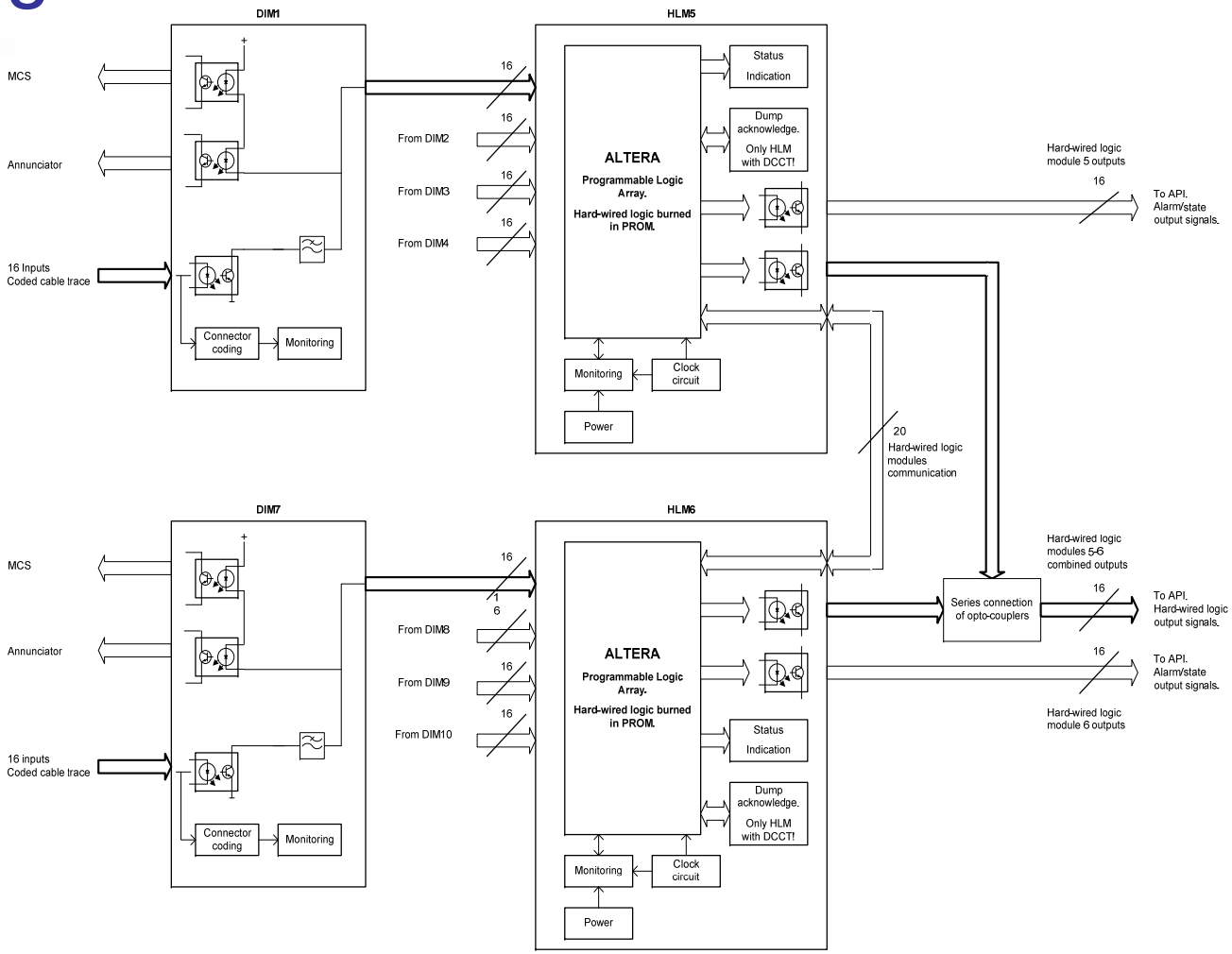
Block Diagram – Analogue Module



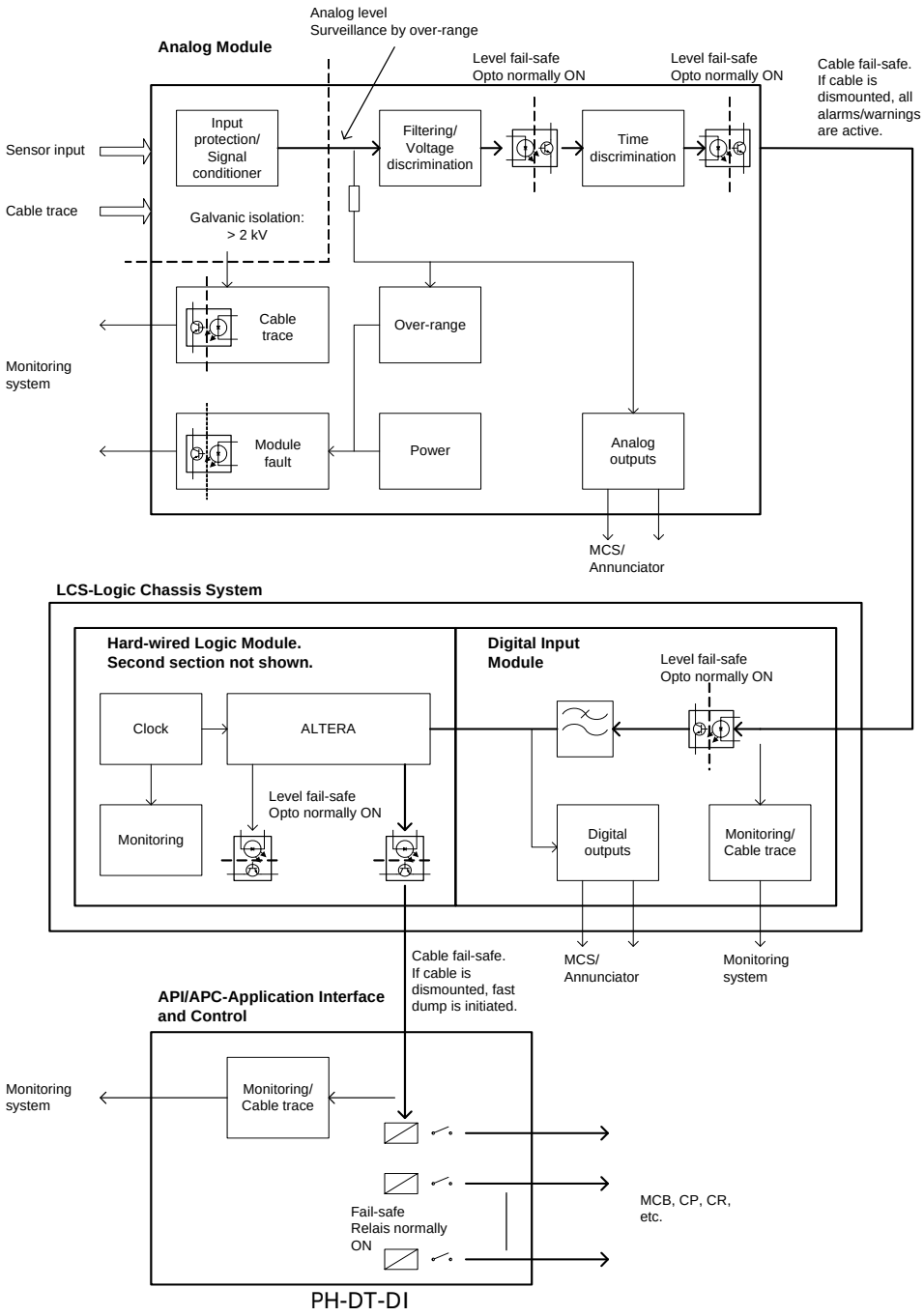
LCS
Block Diagram

DIM: Digital Input Module

HLM: Hard-wired Logic Module



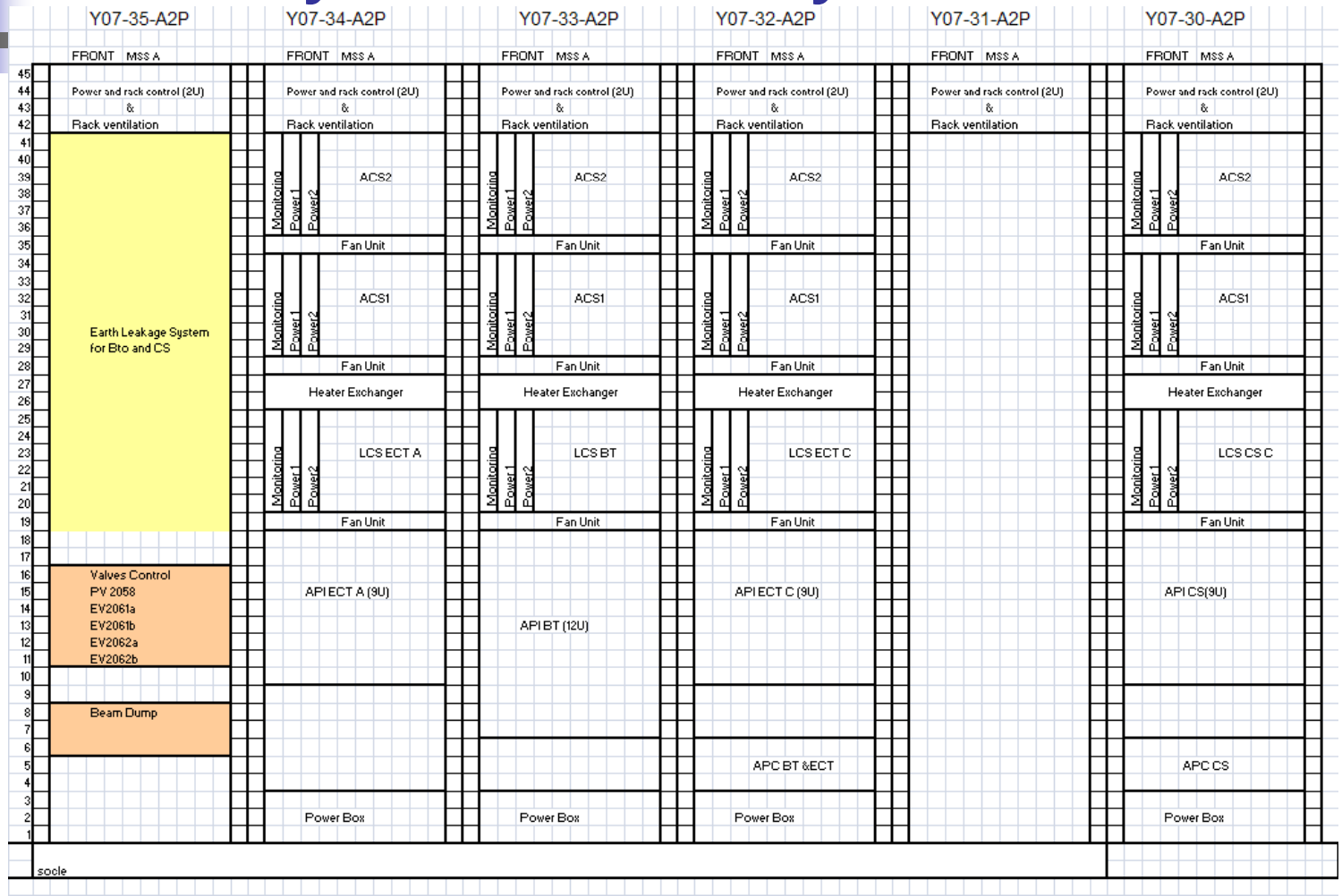
Fail-safe


Analog level
Surveillance by over-range
Analog Module
Level fail-safe
Opto normally ON
Level fail-safe
Opto normally ON
Cable fail-safe.
If cable is
dismounted, all
alarms/warnings
are active.
Sensor input
Cable trace
Input
protection/
Signal
conditioner
Filtering/
Voltage
discrimination
Time
discrimination
Galvanic isolation:
> 2 kV
Cable
trace
Over-range
Monitoring
system
Module
fault
Power
Analog
outputs
MCS/
Annunciator
LCS-Logic Chassis System
Hard-wired Logic Module.
Second section not shown.
Digital Input
Module
Level fail-safe
Opto normally ON
Clock
ALTERA
Level fail-safe
Opto normally ON
Monitoring
Digital
outputs
Monitoring/
Cable trace
Cable fail-safe.
If cable is
dismounted, fast
dump is initiated.
MCS/
Annunciator
Monitoring
system
API/APC-Application Interface
and Control
Monitoring
system
Monitoring/
Cable trace
Fail-safe
Relais normally
ON
MCB, CP, CR,
etc.

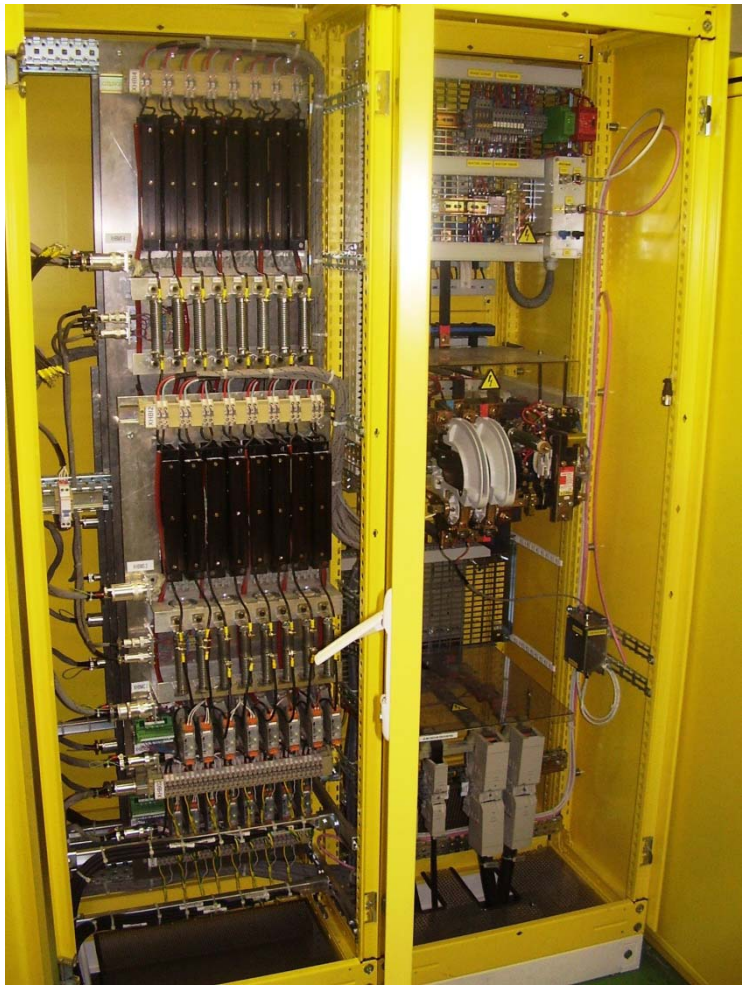
MSSA-B - ATLAS


EARTH LEAKAGE CURRENT DETECTION
ATLAS TOROID
EARTH LEAKAGE CURRENT DETECTION
ATLAS SOLENOID

MSS – System Summary - MSSA



MSS – HEC



System summary - ATLAS

- ATLAS:
  - 8 Racks / 24 analogue chassis / 12 digital chassis
  - Analogue sensor channels (ECT-AC, BT and CS)
    - Bridges: 24
    - Voltages: 28
    - SQD's: 36
    - Temperature: 40
    - Differential: 8

      136
  - Digital inputs / outputs: 1024 / 64
- HEC – Heater Energisation Circuit
  - Heater channels 64
  - Monitoring channels: 128

System summary - CMS

- CMS:
  - 2 Racks / 4 analogue chassis / 2 digital chassis
  - Analogue sensor channels
    - Bridges: 5
    - Voltages: 20
    - Temperature: 8
    - Differential: 5

      38
  - Digital inputs / outputs: 256 / 32

System summary – ALICE - LHCb

- ALICE:
  - 1 Rack / 0 analogue chassis / 2 digital chassis
  - Digital inputs / outputs: 256 / 32
- LHCb:
  - 1/2 Rack / 0 analogue chassis / 1 digital chassis
  - Digital inputs / outputs: 128 / 16

MSS

M

S

S?

Mine

iS not to reason why;

mine iS but to do or die!

MSS

M

S

S?

MSS

More

Salary

to this particular Staff member!