



RESEARCH LABORATORY

MACHINES &
ELECTRONICS

POWER ELECTRONICS & MOTOR DRIVES LABORATORY

FACILITY

- T-Slot Electric Machine Dyno Tables (x8)
- Power Electronics Testing Workstations (x5)

TESTING & PROTOTYPING

- Inverters
- DC/DC Converters
- Battery Chargers
- Solid State Switches
- Electric Machines

Three Phase Power Access

- 208 V, 50 A (x3) ¹
- 480 V, 20 A (x1) ²
- 480 V, 40 A (x3) ³
- 480 V, 80 A (x1) ⁴

High Power DC Power Supplies (x3)

- Output: 375 V, 27 A (x1) ²
- Output: 300 V, 30 A (x2) ¹

Low Power DC Power Supplies (x2)

- Output: 30 V, 15 A
Input: 120 V_{AC} 1ph
- Output: 35 V, 5 A
Input: 120 V_{AC} 1ph

Electronic DC Load

- 600 V, 300 A
- 400 V, 420 A

Room Dimensions

- 18 x 10 m, 1,743 ft²

PROTOTYPING EQUIPMENT:

METERS & PROBES

- LCR/ESR Meter
- Voltmeter (x2)
- Multimeters (x3)
- Current Clamp Meter
- Milliohm Meter
- Digital Thermometer
- Current Probes (x3)
- High Voltage Differential Probes (x6)

TEST & MEASUREMENT

- 10 kHz - 1.5 GHz Spectrum Analyzer
- 20 kHz Function Generator
- 200 MHz 4ch Oscilloscopes (x3)
- dSPACE Microbox
- 100 Ω 2 kW (x4)
- 100 Ω 0.5 kW (x2)
- Soldering Station (x2)

MARC 115

McMaster Automotive Resource Centre (MARC)
200 Longwood Road South, Hamilton, Ontario, Canada L8P 0A6

1. Socket 15-50
2. Socket L17-30
3. Socket GLOBETRON 560W7W
4. Junction box



Funded by the Ontario Ministry of Research and Innovation and McMaster University (PI: Dr. Ali Emadi)

MACHINES & EQUIPMENT

DRIVER-IN -THE-LOOP

DRIVING SIMULATOR

HARDWARE

- Full Vehicle Assembly
- 210° FOV, 7 m Ø Screen
- 3x Projectors (2,560 x 1,600 @ 120 Hz)
- 3D Surround Sound System
- Tunable Steering Feedback
- Complete brake hydraulics
- Pneumatic Active Seat
- Active 5-point Seatbelt

SOFTWARE

- VI CarRealTime
- SimWorkbench
- Matlab Simulink
- VIRES Virtual Test Drive

TESTING

- Drive-before-build
- Energy Management Systems
- Drivability
- Vehicle Dynamics
- Human Machine Interface
- Autonomous Systems
- Human-machine Transition
- Driver Behaviour
- Driving Conditions
- Model Integration
- Component Validation

Server

- iHawk Rackmount with two 3.2 GHz Xeon 8-Core CPUs
- Physical Memory: 1.5 TB
- RAM: 32 GB
- Cache: 25 MB
- Bus Speed: 9.6 GT/s

Graphics

- BARCO F50 WQXGA
- NVIDIA GeForce RTX 2080 Ti
- 27 GB Memory
- VRAM: 11 GB

Room Dimensions

- Control Room: 10 x 3 m, 323 ft²
- Dyno & Simulator Room: 18 x 10 m, 1,937 ft²

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EQUIPMENT & DYNAMOMETERS

VEHICLE DYNO

CHASSIS DYNAMOMETER

TESTING

- Full Vehicle Tests
- Machines & Inverters
- Vehicle-To-Grid
- Differential Wheel Torques & Speeds
- Vehicle & Powertrain Controls

SOFTWARE & CONTROL

- AVL Puma 2.0
- Lynx
- AVL Concerto
- Vector CANoe

COMMUNICATION & MEASUREMENT

- Direct IO & CAN Connection to Driving Simulator
- CAN up to 1kHz
- 32 Thermocouple Inputs
- 16 General Purpose Analog Inputs
- Vector CAN Hardware

AUXILIARY HARDWARE

- Vehicle Cooling Fan (up to 130 km/h)
- Stahle Remote Pedal Actuator
- Full Vehicle Mounting System
- Mobile Vehicle Lift
- Mobile IO Box
- 5-ton Overhead Crane
- Cast Fixture Bedplate

Chassis Dyno

4 Independent Low Inertia Machines:

- 4 x 250 kW Max Power
- 4 x 3,000 Nm Max Torque
- 4 x 3,000 rpm Max Speed
- $\approx 1 \text{ kgm}^2$ inertia
- Meas. Accuracy 0.05%

Battery Emulator / Fast Charger¹

- 8 - 800 V_{DC}
- $\pm 600 \text{ A}$, $\pm 160 \text{ kW}$
- $\pm 0.1\%$ Accuracy
- J1772 Combo, 125 A (500 A soon)

Three Phase Power Access:

- 480 V, 40 A (x3)²

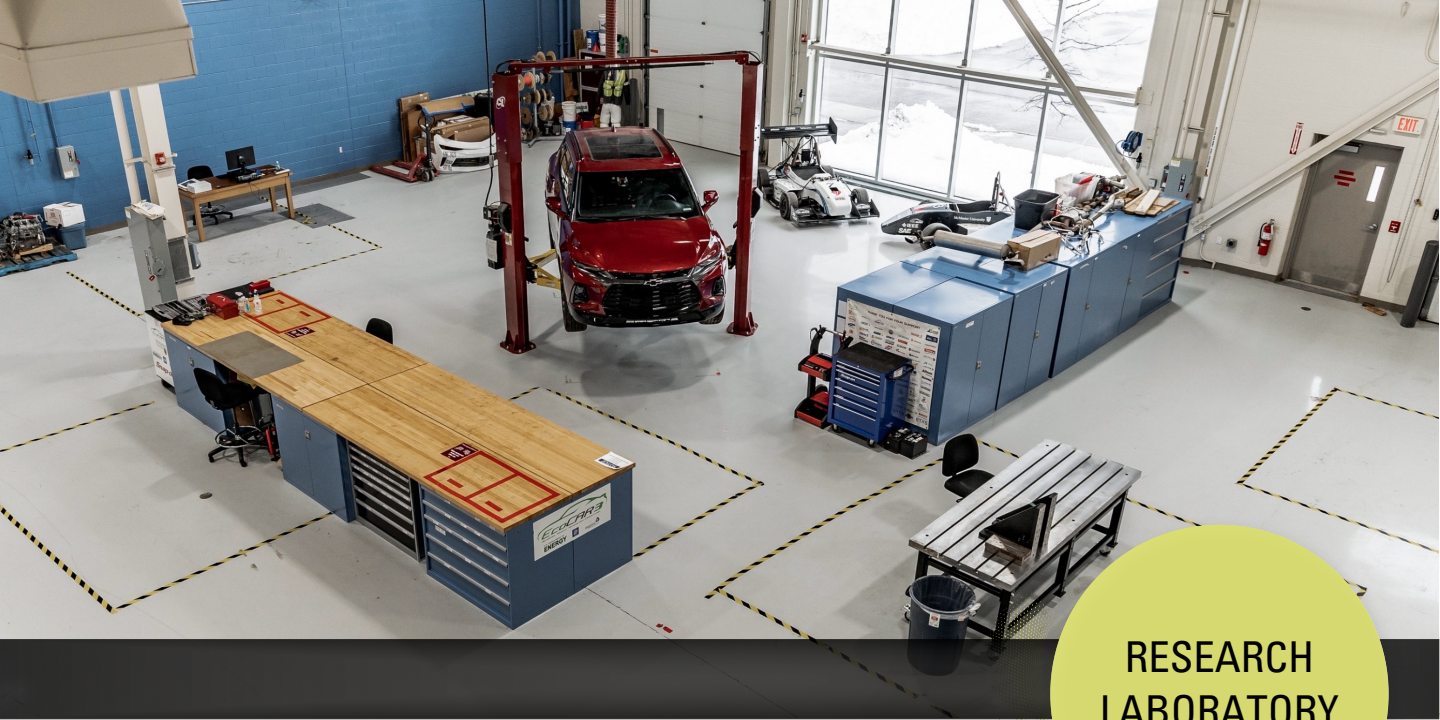
Room Dimensions

- Control Room: 10 x 3 m, 323 ft²
- Dyno & Simulator Room: 18 x 10 m, 1,937 ft²

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¹ AVL BTE 160
² Socket GLOBETRON 560W7W



RESEARCH LABORATORY

ELECTRIFIED
VEHICLES

HIGH BAY LABORATORY

FACILITY

- Hydraulic Car Lift
- T-Slot Electric Machine Dyno Tables (x1)
- Power Electronics Testing Workstations (x1)
- Wooden Work Bench (x6) Dimensions 3 x 0.75 m
- Exhaust Extractor (x4)
- Car Jack
- Short Jack Stands (x2)
- Tall Jack Stands
- Transmission Jack
- Air Hookup

TESTING & PROTOTYPING

- Inverters
- DC/DC Converters
- Battery Chargers
- Solid State Switches
- Electric Machines

PROTOTYPING EQUIPMENT

- Solder Station
- High Voltage Differential Probes (x4)
- Low Voltage Power Supplies (x3)
- Oscilloscopes (x1)
- Multimeters
- Current Probes
- dSPACE MicroAutoBox (x2)
- dSPACE HIL
- Digital Multimeters Fluke
- Thermal Camera

Room Dimensions

- 23 x 21 m, 5,199 ft²

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RESEARCH LABORATORY

MACHINES &
ELECTRONICS

AUTOMOTIVE / AEROSPACE ELECTRIFICATION LABORATORY

FACILITY

- T-Slot Electric Machine Dyno Tables (x2)
- Power Electronics Testing Workstations (x4)
- Meeting Space for Conference Calls
- Building Liquid Cooling Loop Access (up to 30 kW)

TESTING & PROTOTYPING

- Inverters
- DC/DC Converters
- Battery Chargers
- Solid State Switches
- Electric Machines

Bidirectional Grid Simulator (x1) ^{1,2}

- 24 kW, 63 kVA, AC or DC
- 0 - 350 V_{AC-RMS}, 400 V_{DC}
- 30 - 880 Hz
- 60 A_{RMS/DC} per phase
- Parallel for 180 A_{RMS/DC}

Bidirectional DC Power Supplies (x3) ^{2,3}

- 0 - 2,000 V_{DC}
- ±30 A, 20 kW
- Parallel Connection Up to 60 kW, ±90 A_{DC}

PROTOTYPING EQUIPMENT

- Solder Station
- PLECS RT Box
- dSPACE MicroAutoBox
- 30 V, 5 A, Low Voltage Power Supplies (x2)
- 350 MHz 4ch Oscilloscopes (x2)
- Tools & Multimeters (x2) for General Use

Three Phase Power Access

- 208 V 50 A (x1) ⁴
- 208 V 70 A (x1) ⁸
- 480 V 20 A (x1) ⁵
- 480 V 40 A (x3) ⁶
- 480 V 50 A (x1) ⁷
- 480 V 400 A (x1) ⁸

Room Dimensions

- 10 x 9 m, 969 ft²

1. NHR 9410-24, 480 V 58 A 3ph input
2. Equipment is shared between MARC 121 & MARCdrive Laboratories
3. Keysight RP7973A, 480 V 35 A 3ph input
4. Socket NEMA 15-50 50
5. Socket L17 30P
6. Socket GLOBETRON 560W7W
7. Socket Arktite AR642
8. Junction box

MARC 121

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RESEARCH LABORATORY

MACHINES &
ELECTRONICS

MOTOR CONTROL & POWER ELECTRONICS LABORATORY

FACILITY

- T-Slot Electric Machine Dyno Tables (x2)
- Liquid Cooling System

TESTING & PROTOTYPING

- Inverters
- DC/DC Converters
- Battery Chargers
- Solid State Switches
- Electric Machines

PROTOTYPING EQUIPMENT

- 6 kV High Voltage Differential Probes (x3)
- 30 V, 5 A, Low Voltage DC Power Supplies (x2)
- 600 A Rogowski Current Probe (x3)
- Audio Interface & Microphone for Acoustic Noise Measurement*
- 200 MHz 4ch Oscilloscope (x1)
- Solder Station (x2)
- dSPACE MicroAutoBox (x1)
- Tools & Multimeters (x3) for General Use

*Shared with MARC 115

DC Power Supplies (x2)^{1,2}

- 0 - 200 V
- 0 - 210 A, 15 kW
- Parallel Connection
Up to 420 A, 30 kW

Three Phase Power Access

- 208 V, 50 A (x2)²

Room Dimensions

- 10 x 5 m, 538 ft²

1. Keysight N8932A
2. Socket 15-50

MARC 122

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Funded by the Canada Foundation for Innovation (CFI), Ontario Ministry of Research, Innovation, and Science, and McMaster University (PI: Dr. Ali Emadi)

EQUIPMENT &
DYNAMOMETERS

POWERTRAIN
DYNO

POWERTRAIN TESTER THREE MACHINE

TESTING

- HEV Drivetrains
- Electric Machines
- Electric Vehicle Drivetrains
- Differentials
- Gearboxes

SOFTWARE & CONTROL

- A&D Technology Inc Software Tools
- iTEST
- Test Manager
- Procyon / Andromeda (HIL)
- Constant Speed & Vehicle Load Emulation

COMMUNICATION & MEASUREMENT

- CAN
- Thermocouples (16ch, Type K)
- Analog Inputs (16ch, 0 - 10 V)
- Pressure (8ch)
- Torque & Speed Sensors on Each Machine

AUXILIARY HARDWARE

- 20 kW Liquid Cooling / Heating System
- Main & Precharge Contactors
- Switched 12 V, 60 A Supply
- 400 & 700 A_{RMS} Inverters for Machine Characterization

Engine Emulator (Input Dyno)

- 210 kW_{cont} 294 kW_{peak}
- 1,003 Nm_{cont} 1,404 Nm_{peak}
- 2 kRPM_{corner} 8 kRPM_{peak}

Load Machines (Output Dynos)

- 157 kW_{cont} 220 kW_{peak}
- 2,500 Nm_{cont} 3,500 Nm_{peak}
- 600 RPM_{corner} 4,300 RPM_{peak}
- Total Axle Load: Up to 440 kW

Battery Emulator

- 150 kW, ± 250 A_{DC}, 0 - 600 V_{DC}

Regenerative Grid Connection

- 185 kW, 480 V_{AC} 3-phase

Three Phase Power Access:

- 208 V, 20 A (x3) ¹
- 208 V, 30 A (x2) ²

Room Dimensions

- 10 x 9 m, 969 ft²

¹. Socket 15-20
². Socket L15-30

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RESEARCH LABORATORY

BATTERIES &
ULTRACAPS

ENERGY STORAGE LABORATORY

FACILITY

- Fire Suppression & Gas Sensing Equipment Integrated with Chamber & Cyclers

TESTING & PROTOTYPING

- Li-ion Batteries
- Supercapacitors
- Cells & Packs
- Battery Management Systems
- Thermal Management Systems
- Characterization & Aging Tests

Battery Cyclers

1. Digatron Cell Tester (8 x 75 A / 5 V) ¹
2. Arbin Cell Tester (8 x 60 A / 5 V) ²
3. Custom Cell Tester w/ EIS (1 x 120 A / 6 V) ²
4. D&V Pack Tester (2 x 400 A / 500 V / 120 kW)
5. AVL Pack Tester (1 x 600 A / 800 V / 160 kW)

PROTOTYPING EQUIPMENT

- High Voltage Toolbox
- Cell Tab Welder
- Thermal Camera
- 1 kW Chiller
- BMSs & DAQs
- Stocked Components
- High & Low Voltage Battery Packs (x7)

Thermal Chambers

- 3x -40° to 70° C (104 ft³⁴, 16 ft³², 8 ft³²)
- 1x 5° to 94° C (1.37 ft³)

Automated Safety Systems

- Explosive Gas Detection & Explosion Proofing
- CO₂ Fire Suppression System Tied to Building

Three Phase Power Access:

- 208 V, 30 A (x1) ³
- 208 V, 30 A (x3) ²
- 208 V, 50 A (x1) ¹
- 480 V, 60 A (x1) ⁴

Room Dimensions

- 4 x 7 m, 301 ft²

1. Socket Hubbell CS8365C
2. Socket L15-30
3. Socket L14-30
4. Socket Arkrite AR642

MARC 130

Centre for Mechatronics and Hybrid Technologies (CMHT)
McMaster Automotive Resource Centre (MARC)
200 Logwood Road South, Hamilton, Ontario, Canada L8P 0A6



Funded by the Canada Foundation for Innovation (CFI), Ontario Ministry of Economic Development and Innovation, & McMaster University (PI: Dr. Saeid Habibi; Co-PI: Dr. Ali Emadi)

**EQUIPMENT &
DYNAMOMETERS**

HIGH SPEED ELECTRIC MACHINE DYNO

**ELECTRIC
MACHINE
DYNO**

TESTING

- Electric Machines
- High Power Inverters
- Integrated Machines & Inverters
- Controls

COMMUNICATION & MEASUREMENT

- CAN up to 1 kHz
- 16 High Voltage Inputs (1,000 V)
- 32 General Purpose Analog Inputs (Thermocouple, RTD, etc)
- Yokogawa WT1800 Power Analyzer

SOFTWARE & CONTROL

- AVL PUMA
- EMCON 400 Test Rig Controller
- AVL InMotion Simulation System

AUXILIARY HARDWARE

- 20 kW Liquid Cooling / Heating System
- Main & Precharge Contactors
- Switched 12 V 60 A Supply
- 400 & 700 A_{RMS} Inverters for Machine Characterization

Dyno Machine¹

- 250 kW Max Power
- 500 Nm Max Torque
- 22,000 rpm Max Speed
- 60,000 rpm/s Max Accel.
- Meas. Accuracy 0.05%

Bidirectional Supply for Test Machine²

- DC, Two Channels
- 500 V, 400 A, 120 kW / Channel
- Series or Parallel Connection
- Max 1,000 V or 800 A, 240 kW

Room Dimensions

- 4 x 4 m, 172 ft²

1. AVL TK 250
2. D&V Power Electronics BST240

MARC 132

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