Miniaturized Motor Controller for Space Robotic Applications

“Motion Control Chip”

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About ÅAC Microtec AB…

✔ Formerly named Ångström Aerospace Corporation
✔ Two business units
  - **Miniaturized and Robust Industrial Electronics**
  - **Space and Defense**
✔ Academic spin-off company from Uppsala University, The Ångström Laboratory
✔ Privately owned
✔ Internal clean room (class 100 and 1000) and assembly facility
✔ Turn over ~3.5 M Euro

✔ CEO, Mats Magnell, Ph.D. (f.m. Scania, Mydata, ABB)
✔ V.P., Fredrik Bruhn, Ph.D. (co-founder, f.m. Uppsala Univ., NASA JPL)
✔ Corporate Board
  - Chairman, Staffan Junel (f.m. V.P. Ericsson, CEO Hasselblad)
  - Sven Löfqvist (f.m. CEO Micronic Laser Systems)
  - Stefan Hanna (f.m. Ericsson M&A, IBM, Industrimatematik)
  - Olof Stjernberg (f.m. CEO Wasakredit)
Motivation

• ExoMars design includes more than 40 electrical motors
• Each motor requires control electronics
• Miniaturization of electronics, out of the hot box
  – Saving in volume, mass, energy

Image courtesy of ESA.
Introduction to MCC

- ESA TRP started in 2008, ÅAC Microtec AB prime
- Miniaturized Motion Control module for Cold Space environment
- Storage -120 °C to 70 °C
- Operational -55 °C to 70 °C
- Close cooperation with ExoMars team
- ~ 700 requirements (Selex Galileo/Astrium)

- Based on ÅAC packaging technology
- Distributed operation with only +28 V and CAN interface,
  – Software controlled (32-bit processor)
  – Current control loop >= 10 kHz

- Use of Nano-D connectors (space qualified by ESA)

- Modularized design for individual parts to be reused for other purposes
MCC operation overview

MCC

+ 28 V

CAN

H-bridge

H-bridge

H-bridge

Sensor inputs
MCC supported sensors and motors

- 3 Brushed or 1 brushless motor operation in triple modes:
  - Position
  - Velocity
  - Torque

- Maxon (Brushed), RE13, RE20, RE25
- Maxon (Brushless), EC22, EC40, EC60

- A wide range of sensor inputs

- Current loop frequency 10 kHz
- Outer loop frequency 1 kHz
- PWM frequency settable 20-100 kHz
Hybridization and silicon interposer technology

Digital part (MCC-C)  Analog part (MCC-MD)
Assembly flow
MCC-C

• ÅAC XiVIA® Thru-silicon-Via (TSV) interposer technology
• MicroSemi/ACTEL ProAsic A3P3000E FPGA
  – LEON3-FT (Gaisler) or OpenRISC 1200-FT (ÅAC)
  – Processor clock 25 MHz
  – Scheduler from CSEM
  – Direct memory mapping (no RTEMS drivers)
  – PWM IP
  – Redundant, isolated CAN 2.0
  – SpaceWire (optional)
  – Alternative, RTL control loop

• 2 MB of SRAM
• 16 Mbit of Flash
• Galvanic isolation of communication
• ADC, 12 bit, 500 kHz
• CAN phy, 3.3 V
• Linear power regulation
• 34 x 34 x 3 mm3
MCC-MD

- 3 H-bridges (28 V @ 5 A)
  - 3 Brushed or 1 Brushless
  - 4 quadrant mode (<= 150 W)
- Motor heater (<= 90 W)
- Isolated temperature measurement
- EMI filtering
- 80 x 40 x 6 mm³
MCC-Power Supply Unit (PSU)

- Self resonant fly-back architecture (Designed in cooperation with ESA.

- +28 V input
- +12 V output
- -12 V output
- 7 V output
- 5 V output
MCC Casing
See the MCC in action, Visit the exhibition in "Einstein"
Control software environment (CSEM)
Movie showing operation of MCC
Results and current status

- 6 MCC units manufactured
- Challenges with process flow of ADC, SRAM, and Flash
- Electrically partially verified

- Power figures (more than half is lost in linear regulation):
  - Standby power 4 W,
  - Running 3 brushed motors simultaneously in torque and position mode 9 W.
- Weight:
  - Electronics 30 grams
  - Casing and connectors: 270 grams
  - Total: 300 grams

- Next step is TRR and following testing (DLR)

- The MCC needs another iteration to mature. But the result so far is really encouraging and promising
Acknowledgments

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- For more information, go to
- http://www.aacmicrotec.com