NVIDIA® Tegra K1
IMPOSSIBLY ADVANCED
first ARM SoC with integrated CUDA

- deploy battery-powered CUDA for data-intensive applications
- more perception → more autonomy!
- outpace the growth of sensors and increasing algorithmic demands
- rapid development & prototyping in a realtime-capable environment
- wide-ranging CUDA code compatibility → reduced risk & cost
- developer-friendly tools and Linux SW ecosystem
robotics

- UAV  UUV  UGV
- humanoids, mechs, and cybernetics
Tegra’s... in space
sensing, surveying & surveillance
scientific
medical
industrial

• portable analyzers, sequencers, and scopes

• handheld ultrasound, CT, MRI, X-ray

• RF signal processing

imagination at work
GE launches TK1 mini module

New COM Express Module from GE Brings New Levels of Performance to Applications Constrained by Power Consumption and Size

- mCOM10K1 delivers 326 GFLOPS of performance, consumes 10 watts or less
- Benefits from NVIDIA® Tegra® K1 GPU for data-intensive platforms
- Allows GE to respond to growing demand for SWaP-constrained solutions

NUREMBERG, DE—FEBRUARY 24, 2015—GE’s Intelligent Platforms business today announced at Embedded World the mCOM10K1 type 10 Mini COM Express module. Based on the NVIDIA® Tegra® K1 system-on-chip (SoC) - enabling it to deliver 326 GFLOPS of performance, well beyond the performance typically associated with Mini COM Express - it is ideal for applications where very high performance in data-intensive applications, rugged reliability in harsh environments and very compact size need to be combined.

As well as extending GE’s COM Express offering still further, the mCOM10K1 also brings GE’s powerful GPGPU (general purpose processing on a graphics processor) capability within reach of the significant number of applications where power consumption needs to be 10 watts or less.
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COM Express mini module

**Processor/Chipset**
- NVIDIA Tegra K1 SOC
  - 4 Core ARM Cortex-A15 @ 2.0 GHz, <10W TDP
  - 192 Kepler GPU cores (CUDA capable)

**Memory**
- 2GB of DDR3

**Memory**
- 4GB of eMMC flash

**Graphics Features**
- Integrated graphics interface
  - HDMI
  - LVDS

**Audio**
- Stereo line out / Stereo line in

**LAN Port**
- 1x Gigabit Ethernet port (SKU-A only)

**Serial ATA Interface**
- 1x serial ATA interfaces (3 Gb/s)

**USB Interface**
- 5x USB 2.0 ports
- 1x USB 3.0 ports (SKU-A only)

**Extension**
- PCIe, 1 port x2 Gen 2 (SKU-A)
- PCIe, 1 port x4 Gen 2 (SKU-B)

**I/O Interface**
- 8x GPIO ports

**Others**
- States: Active, Suspend (LP1), Deep Sleep (LP0)
- Debug port
- convenient MIPI CSI-2 connector port
- pre-mounted passive heat sink/spreader for optimal cooling
- 7-year long lifecycle guaranteed availability

**Power**
- Input: 12V
- 10 watts

**Environmental**
- Operating: 0° to +65° C (standard)
- Operating: -40° to +75° C (extended; CPU dependent)
- Vibration: 15 – 2000 Hz, 0.1 g2 / Hz.
- Storage: -40° to +125° C
- Operating humidity: 10% to 90%
- Shock: 40 g, 11 ms
- Vibration: 15 – 2000 Hz, 0.1 g2 / Hz.
- Conformal coating available.

**Dimensions**
- 55 mm x 84 mm
- COM Express mini form factor; Type 10
- Compliance: PICMG COM Express R2.1

**Software Support**
- Linux4Tegra (Ubuntu 14.04)
- CUDA Toolkit 6.0 and 6.5
- OpenGL 4
MC10K1 layout
MC10K1 layout
MC10K1 – SKU-A

NVIDIA Tegra K1

- 2x CSI-2
- 2x CSI-2

- DDR3
- DDR3
- PCIe
- PCIe (Gen 2)

- i210
- Codec

- 12 V_{dc}
- 1x GbE
- x2 PCIe (Gen 2)
- 1x USB3
- 5x USB2
- 1x SATA (3 Gb/s)
- 8x GPIO
- 1x HDMI
- 1x LVDS
- 1x Stereo line in
- 1x Stereo line out
MC10K1 – SKU-B

- NVIDIA Tegra K1
- DDR3
- DDR3
- PSU
- 12 Vdc
- x4 PCIe (Gen 2)
- 5x USB2
- 1x SATA (3 Gb/s)
- 8x GPIO
- 1x HDMI
- 1x LVDS
- 1x Stereo line in
- 1x Stereo line out
- 2x CSI-2
small form-factor (SFF)

- COM Express mini – among smallest industry-standard form factors

<table>
<thead>
<tr>
<th>form factor</th>
<th>dimensions</th>
<th>surface area</th>
<th>connector</th>
</tr>
</thead>
<tbody>
<tr>
<td>COM Express compact</td>
<td>95x95mm</td>
<td>9025mm²</td>
<td>mezz</td>
</tr>
<tr>
<td>PC/104</td>
<td>90x96mm</td>
<td>8640mm²</td>
<td>stack</td>
</tr>
<tr>
<td>SMARC full</td>
<td>82x80mm</td>
<td>6560mm²</td>
<td>edge</td>
</tr>
<tr>
<td>Qseven</td>
<td>70x70mm</td>
<td>4900mm²</td>
<td>edge</td>
</tr>
<tr>
<td>COM Express mini</td>
<td>55x84mm</td>
<td>4620mm²</td>
<td>mezz</td>
</tr>
<tr>
<td>SMARC short</td>
<td>82x50mm</td>
<td>4100mm²</td>
<td>edge</td>
</tr>
</tbody>
</table>

- ruggedization advantage over edge-mount
COM Express mini brick
COM Express mini brick

GE mCOM10K1 module

ConnectTech CCG010 carrier

GE mCOM10K1

CTI CCG010
COM Express mini brick

GE mCOM10K1 module (w/ heatsink)

ConnectTech CCG010 carrier

CTI CCG010

GE mCOM10K1

NVIDIA Tegra K1
COM Express mini brick

integrated mini brick

35mm (stacked height)

GE mCOM10K1

CTI CCG010
rugged CUDA modules

**6U VPX**
- IPN250 (Tesla) Intel + NVIDIA GT215
- NPN240 (Tesla) dual NVIDIA GT215
- MXM940 dual MXM3.0B carrier

**3U VPX**
- GRA111 (Tesla) NVIDIA GT215
- GRA112D (Kepler) NVIDIA EXK107 dual output
- GRA112Q (Kepler) NVIDIA EXK107 quad output
- GRA112V (Kepler) NVIDIA EXK107 legacy RS170 output
- tiled TK1 (Kepler) NVIDIA Tegra K1 custom multi-Tegra

**N/S**
- MC10K1 (Kepler) NVIDIA Tegra K1 COM Express mini

**COMe**
- MC10X1 (Maxwell) NVIDIA Tegra X1 COM Express mini

**IPN251 refresh** (Maxwell) Intel + NVIDIA GM107

**MXM940**
- dual NVIDIA GT215

**MC10K1**
- NVIDIA Tegra K1 COM Express mini

**MC10X1**
- NVIDIA Tegra X1 COM Express mini

**GRA113** (Maxwell)
- NVIDIA GM107 640-core 2GB GDDR5

**GRA111** (Tesla)
- NVIDIA GT215

**GRA112Q** (Kepler)
- NVIDIA EXK107 quad output

**GRA112V** (Kepler)
- NVIDIA EXK107 legacy RS170 output

**IPN250** (Tesla)
- Intel + NVIDIA GT215

**IPN251** (Kepler)
- Intel + NVIDIA EXK107

**MXM940**
- dual MXM3.0B carrier

**IPN251 refresh** (Maxwell)
- Intel + NVIDIA GM107
rugged CUDA modules

- **6U VPX**
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- **COMe**
  - MC10K1 (Kepler)
    - NVIDIA Tegra K1 COM Express mini

**MIL-spec NVIDIA® modules**
- extended-temperature passive cooling
- BGA chip-down packaging
- efficient GFLOPs/watt & SWaP
- smallest industry-standard form factors
- long-term lifecycle support
- SW/HW-compatible product family

**GE, official NVIDIA® partner**
tiled Tegra
triple-redundant Tegra

- PCIe provides higher bandwidth than available with GigE, USB3 → 1-2GB/s
- **challenge:** linking multiple Tegra root complexes together (via non-transparent bridging on PCIe switch)
triple-redundant Tegra

- PCIe provides higher bandwidth than available with GigE, USB3 → 1-2GB/s
- **challenge:** dual-redundant network (via switch failover)
triple-redundant Tegra

- PCIe provides higher bandwidth than available with GigE, USB3 $\rightarrow$ 1-2GB/s
- **challenge**: dual-redundant network (via switch failover)
GE and NVIDIA go to the Moon with Astrobotic

GE to demonstrate at GTC how Rugged GPU-Enabled Embedded Computing can Enable Moon Landing, Exploration

- Astrobotic moon lander, rover feature GE/NVIDIA GPU technology
- Extreme processing performance, minimal power consumption are key to success

SAN JOSE, CA.— March 17, 2015— At NVIDIA’s annual GTC – the demonstration on GE’s GTC stand (# 428) features a moon landing vehicle – “Griffin” - developed by space exploration company Astrobotic as Astrobotic’s entry into the Google Lunar XPRIZE competition.

Onboard the Griffin is GE’s MAGIC1 rugged display computer, equipped with NVIDIA GPU technology. Data from the lander’s onboard cameras, lasers and inertial sensors will be passed to the MAGIC1, which will calculate the lander’s position relative to where it is supposed to be, and provide adjustment feedback to the navigation system.

“There are few, if any, more demanding challenges placed on embedded computing than those presented by space flight and lunar exploration,” said John Thornton, CEO, Astrobotic. “GE has the robust, reliable, high performance – and very cost-effective – technology needed to succeed, and the expertise and experience that has allowed Astrobotic to leverage that technology’s potential.”
• so far, only US, USSR, and China have landed on Moon
• launch window second half 2016 aboard SpaceX Falcon9
• GLXP object – land, rove, and stream H.264 video to Earth
• GE pre-qualified systems help satisfy GLXP milestone req’s
Autonomous Landing & Navigation

- NVIDIA-equipped MAGIC1 system provides real-time georeferencing onboard the lander, permitting navigation to within 100M radius. (compare to 60’s-era moon landings)
Astrobotic—GLXP Milestone Leader

**SUMMARY OF MILESTONE PRIZE WINNERS**

<table>
<thead>
<tr>
<th>Landing ($1 Million each)</th>
<th>Mobility ($500,000 each)</th>
<th>Imaging ($250,000 each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astrobotic (US)</td>
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</tr>
<tr>
<td>Team Indus (India)</td>
<td>Hakuto (Japan)</td>
<td>Moon Express (US)</td>
</tr>
<tr>
<td>Moon Express (US)</td>
<td>Part-Time Scientists (Germany)</td>
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</tbody>
</table>
NASA technology readiness level

- **TRL 9**: Actual system “flight proven” through successful mission operations
- **TRL 8**: Actual system completed and “flight qualified” through test and demonstration (ground or space)
- **TRL 7**: System prototype demonstration in a space environment
- **TRL 6**: System/subsystem model or prototype demonstration in a relevant environment (ground or space)
- **TRL 5**: Component and/or breadboard validation in relevant environment
- **TRL 4**: Component and/or breadboard validation in laboratory environment
- **TRL 3**: Analytical and experimental critical function and/or characteristic proof-of-concept
- **TRL 2**: Technology concept and/or application formulated
- **TRL 1**: Basic principles observed and reported
Tegra K1 deployed on rover for H.264 streaming of stereo HD video sensors over Lunar/Earth ethernet network.
• Compressed IP stream is relayed to the lander’s high-gain antennae and transmitted to a satellite constellation back in Earth orbit.
Piped back to Earth... it's an Internet-of-Thing!
Integrating GPU With Your Program

**DISCOVER**
- Experiment with CUDA on NVIDIA Jetson devkit
- Investigate potential application algorithms for acceleration with CUDA.

**DEVELOP**
- Use VPX lab system to develop CUDA application.
- Integrate GPU solution with any 3rd-party devices (FPGA)
- Preliminary field tests

**DEPLOY**
- Production VPX chassis with dedicated backplane and deployable cooling.
- Full environmental testing and qualification.
- Long-Term Support (LTS)
objectives:

- demonstrate viability of battery-powered CUDA
- complex multi-sensor pipeline on TK1
- upgrade R&D platform for future Jetson’s
- realtime hardware-in-the-loop with TK1
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- demonstrate viability of battery-powered CUDA
- complex multi-sensor pipeline on TK1
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- realtime hardware-in-the-loop with TK1
Battery-Powered CUDA

battery life
>5.5hr per charge!
CUDA applications

Wide-Area Surveillance  Step/Stare Mosaic – 360SA

hyperspectral

RADAR + LIDAR

motion detection

sensor fusion

pedestrian & vehicle detection

SAR imaging

GE tracking
Code-compatible

- **Tegra COMe**: <10 Watts
- **3U VPX**: 100 Watts
- **6U VPX**: Up to 2 kW
Code-compatible

- NVIDIA CUDA/OpenCL
- Intel (or ARM)
- Mellanox (OFED)
- Linux