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VEHICLE ELECTRONICS AND ARCHITECTURE

Michigan Chapter
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National Defense Industrial Association

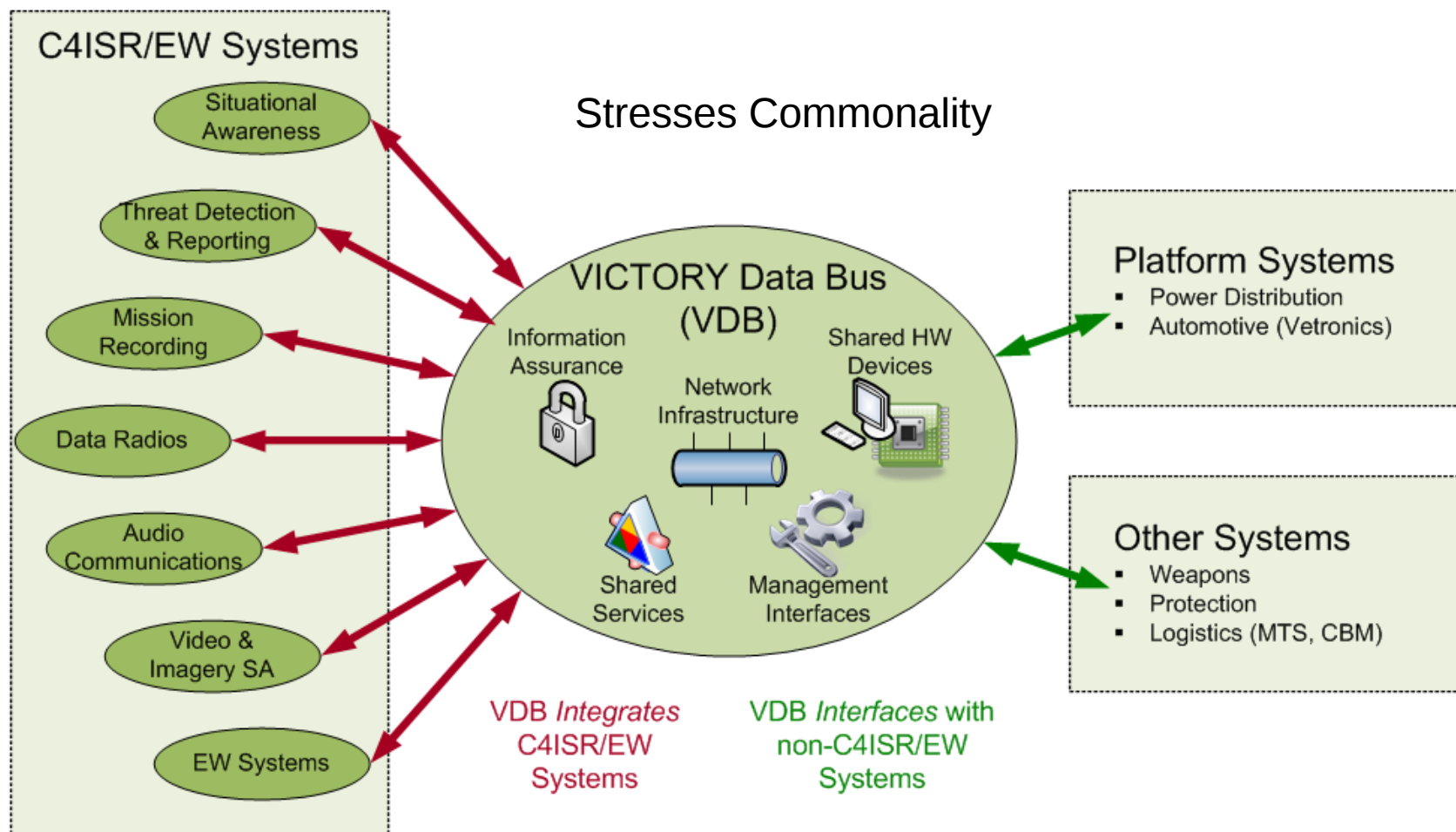
Reduced SWAP-C VICTORY Services

Execution and Performance Evaluation

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14. ABSTRACT -Executing multiple VICTORY data services, and reading multiple VICTORY-compliant sensors at the same time resulted in the following performance measurements for the system -0.64 Amps / 3.15 Watts Power Consumption at run-time. -Roughly 0.77% System Memory Utilization per Service 1.05%, 0.433%., 0.531% average CPU utilization for Position, Direction of Travel, and Orientation Services, respectively. -Less than 1.7 milliseconds processing time (Building and Publishing Full Featured VICTORY XML Messages). -A delta of 68.97 Watts between workstation and BeagleBoard, which is 95.6% more efficient. ?Therefore, boards based on this type of architecture are an excellent candidate for running VICTORY services while providing significant reductions in SWAP-C for the VICTORY 1.0 project.					
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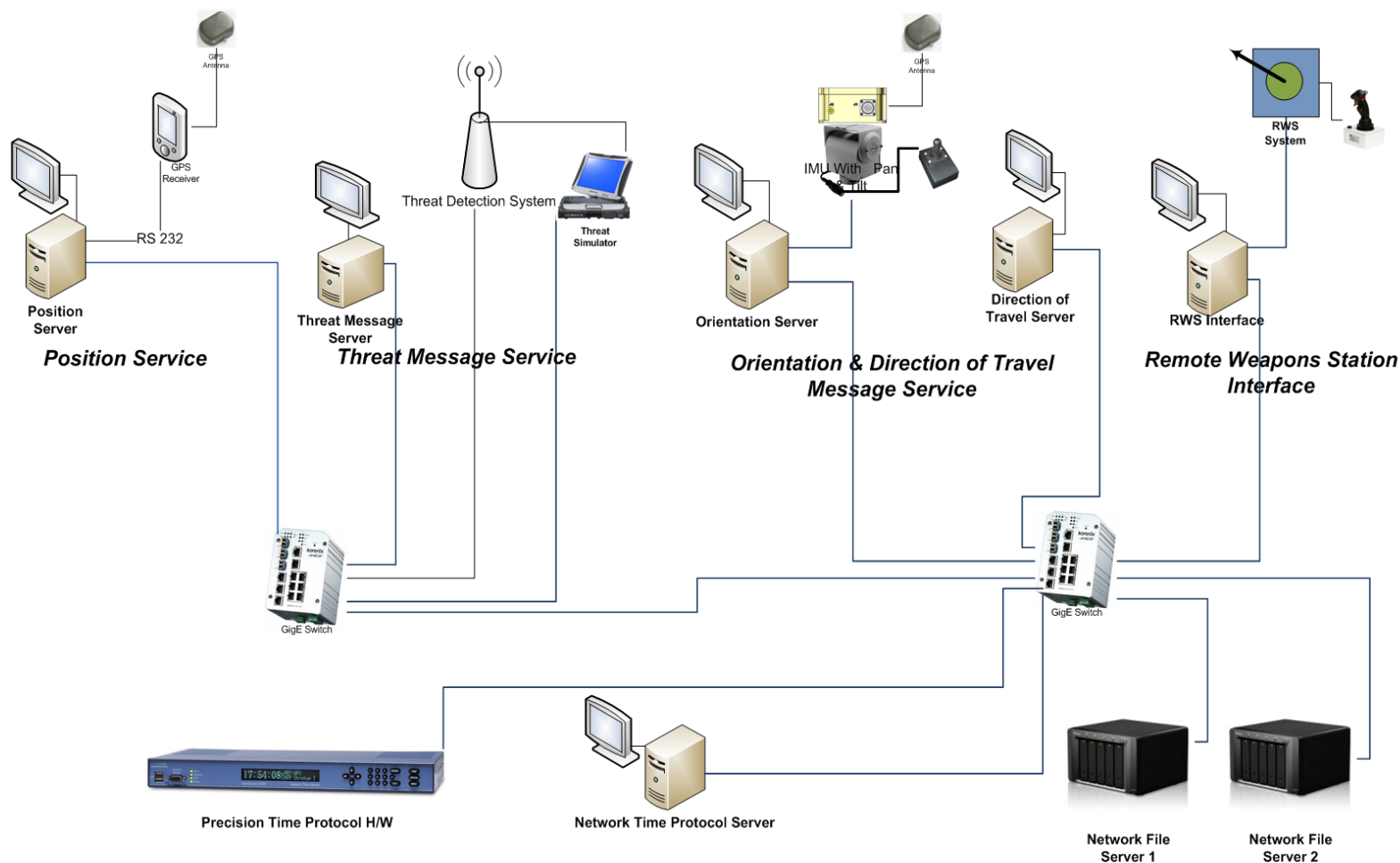
VICTORY Architecture Overview

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VICTORY Services Overview

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Small SWAP-C / Embedded System – The “BeagleBoard”

BeagleBoard – xM

Single Board Computer – Development Board

Hardware:

ARM® Cortex™-A8 CPU
3D graphics accelerator
Multiple external I/O ports

Low Cost:

\$150 / board

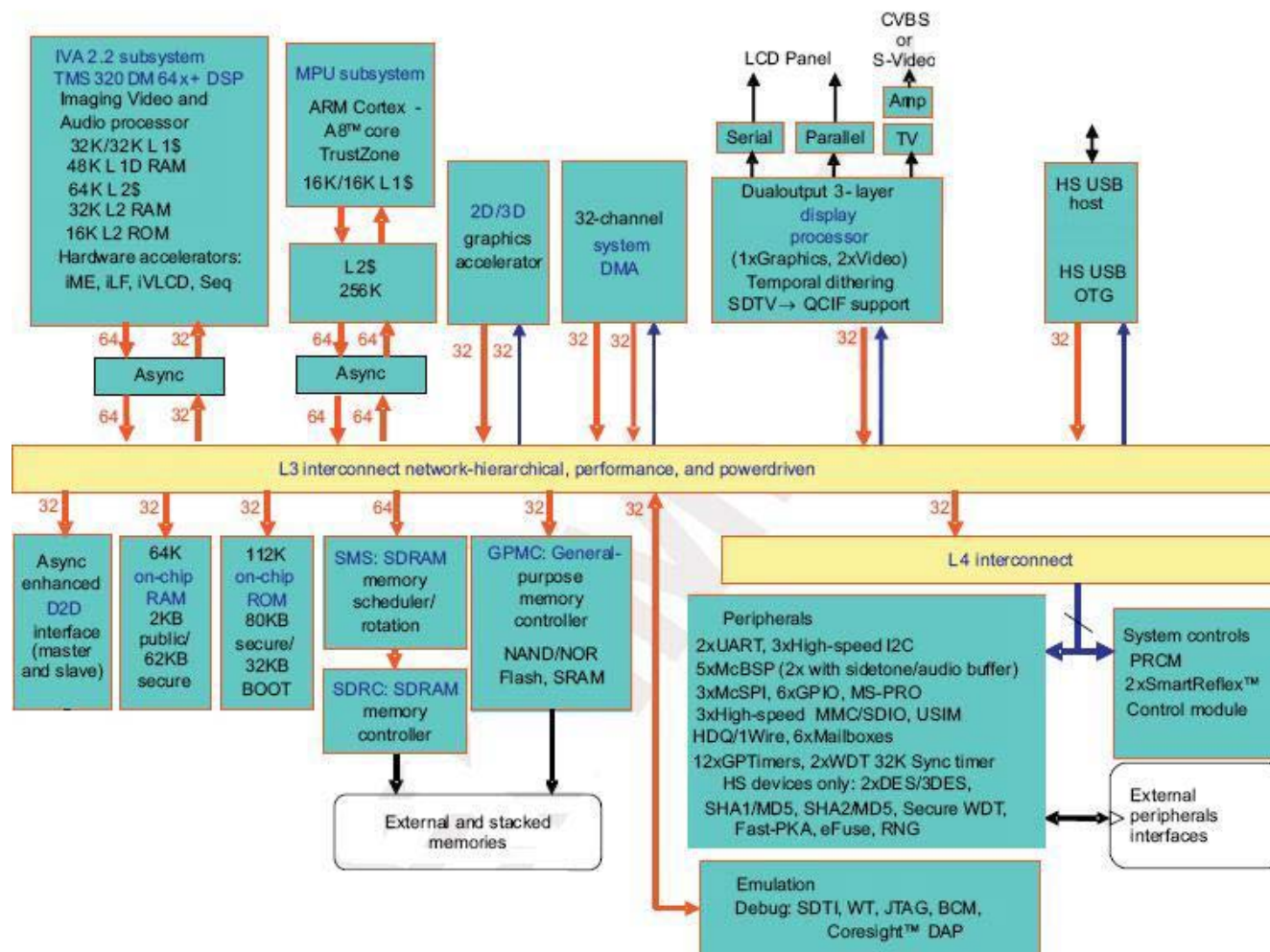
Low Weight:

Around 1 lb.



High Level Block Diagram DM3730 processor

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Microprocessor unit (MPU) subsystem based on the ARM Cortex-A8™ microprocessor

- POP Memory interface
- 4Gb MDDR (512Mbytes)
- 24 Bit RGB Display interface (DSS)
- SD/MMC interface
- USB OTG interface
- NTSC/PAL/S-Video output
- Power management
- Serial interface
- I2C interface
- I2S Audio interface (McBSP2)
- Expansion McBSP1
- JTAG debugging interface

Successful Applications of the Beagleboard



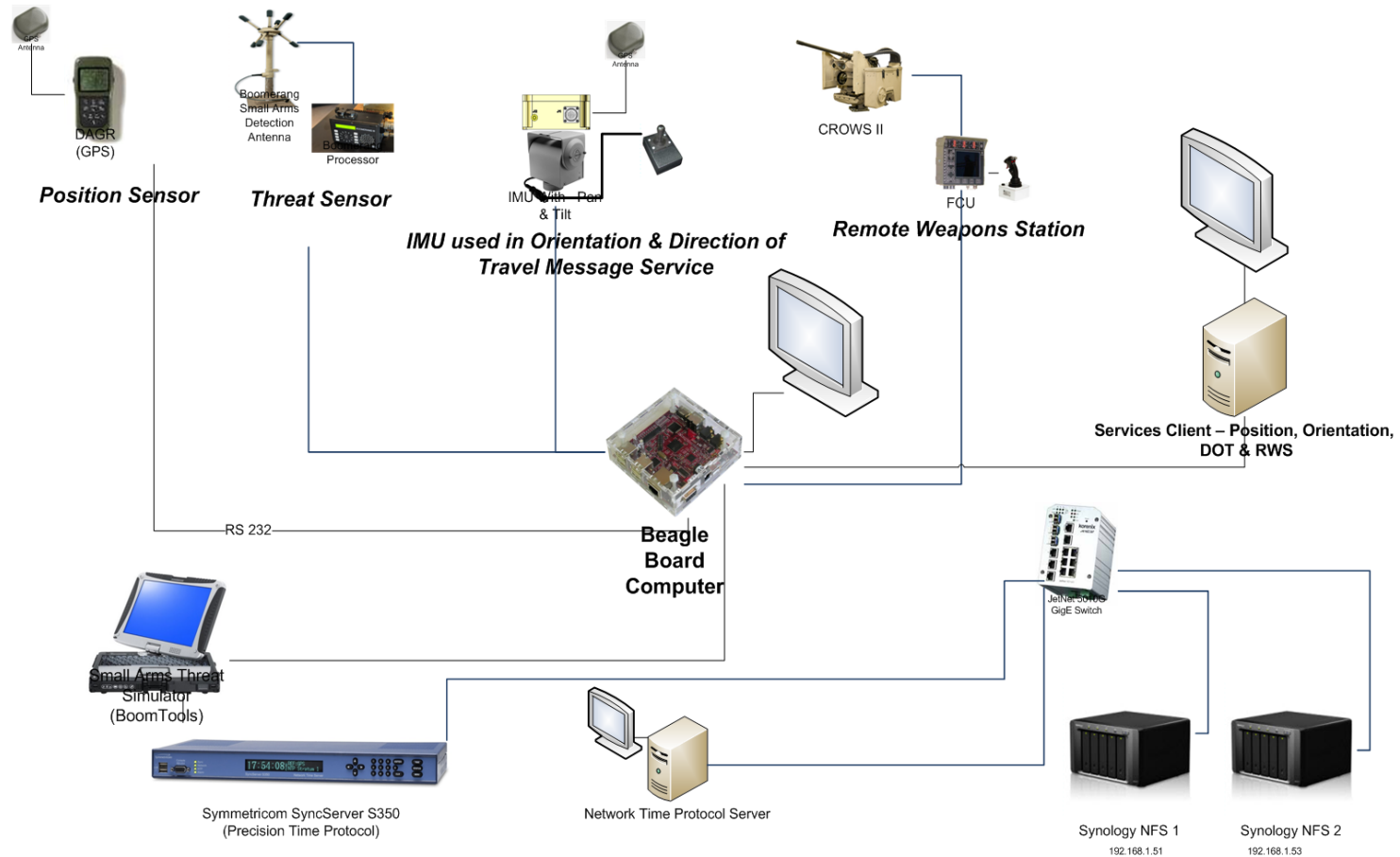
- Popular BeagleBoard Projects
 - Automatic dog-walker robot
 - Location aware weather station
 - Android mini-desktop computer
 - Autonomous All Terrain Vehicle
 - 30 fps full screen OpenGL rendering

- The following Operating Systems have been ported to this architecture:
 - Ubuntu
 - Android
 - Angstrom
 - Symbian
 - Gentoo
 - QNX Neutrino

The “After” Picture for VICTORY Services Running in an Embedded Environment

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VIDS Services Physical Diagram using Beagle Board Computer

O/S & Software Deployment

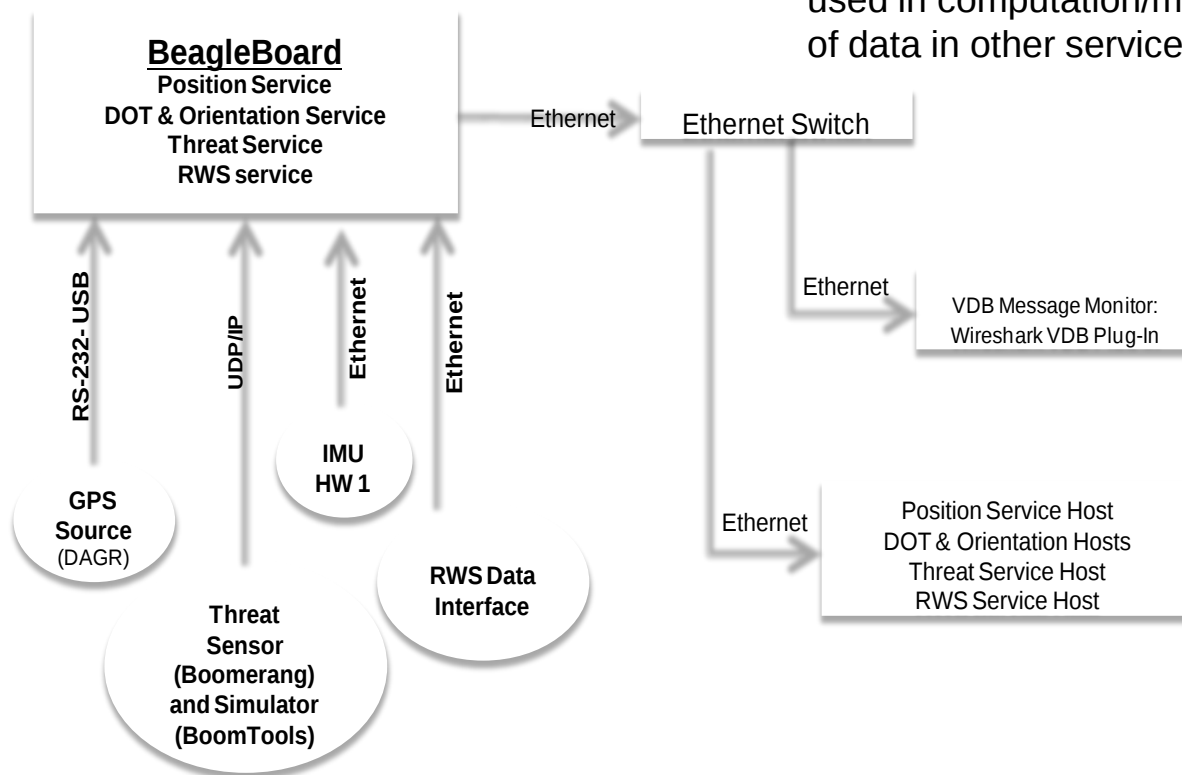


- Finding Suitable Operating System
 - Angstrom – default OS out of the box.
 - Difficulty finding the correct drivers and libraries
 - Ubuntu 10 – quickly switched to this OS as there was much better community support and therefore readily available drivers. (Beagleboard – elinux.org)
 - Difficult to install, given the serial / hyper-terminal interface means of installation. Despite proper connection settings, words and graphics became mangled.
 - Memory card became corrupt, single point of failure. Had to start over from scratch.
- Code-sourcery – open source ARM-GCC compiler
 - Linux development hosts create cross-compiled binaries to run on the target Beagleboard
 - Having issues compiling code against the arm openssl library
 - It is also possible to develop and compile software directly on the hardware itself, although it takes considerable more time.

Physical Interface Diagram for BeagleBoard's Services

- Single point of service for data

Service data consumed. It is displayed/validated, or used in computation/manipulation of data in other services.



Software Benchmarking



- Wish to determine how efficient our SBC BeagleBoard is at running VICTORY services.
 1. Record statistics for each process' system utilization
 2. Determine the amount of memory consumption
 3. Compare processing time of Victory Data Messages
 4. Determine how much overhead comes from the software versus the external sensors / peripherals
 5. Determine the efficiency at which web-based gSOAP service model executes.

Software Benchmarking



- The Linux kernel records the amount of clock cycles that it performs actual work in 1 second. These units are known as Jiffies.
- Each running process stores metadata about itself in the virtual /proc file system. It is possible to obtain the following:
 - (1) The amount of Jiffies per this process. Using this data versus the entire summation of Jiffies for each process executing, you can obtain the percentage of CPU utilization.
 - Trigger data stores for minimum and maximum percentages
 - Obtain average percentage
 - (2) The amount of memory utilization. After our services are instantiated, they do not malloc any data. The memory usage remains fairly constant.

Sample Position Victory Data Message (VDM)

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Capturing from em1 [Wireshark 1.6.5 (SVN Rev Unknown from unknown)]

File Edit View Go Capture Analyze Statistics Telephony Tools Internals Help

Filter: udp.dstport == 49152 Expression... Clear Apply

No.	Time	Source	Destination	Protocol	Length	Info
1226	201.235034	192.168.1.59	239.0.0.1	UDP	652	Source port: 53836 Destination port: 49152
1253	216.529037	192.168.1.59	239.0.0.1	UDP	652	Source port: 53836 Destination port: 49152
1260	221.530601	192.168.1.59	239.0.0.1	UDP	648	Source port: 53836 Destination port: 49152
1269	225.531979	192.168.1.59	239.0.0.1	UDP	648	Source port: 53836 Destination port: 49152
1277	231.533474	192.168.1.59	239.0.0.1	UDP	648	Source port: 53836 Destination port: 49152
1284	236.534931	192.168.1.59	239.0.0.1	UDP	648	Source port: 53836 Destination port: 49152
1294	241.536033	192.168.1.59	239.0.0.1	UDP	648	Source port: 53836 Destination port: 49152
1301	246.537894	192.168.1.59	239.0.0.1	UDP	648	Source port: 53836 Destination port: 49152
1308	251.540500	192.168.1.59	239.0.0.1	UDP	648	Source port: 53836 Destination port: 49152
1452	256.540093	192.168.1.59	239.0.0.1	UDP	648	Source port: 53836 Destination port: 49152
1460	261.542224	192.168.1.59	239.0.0.1	UDP	648	Source port: 53836 Destination port: 49152

Frame 1308: 648 bytes on wire (5192 bits), 648 bytes captured (5192 bits) on Ethernet II, Src: CadmusCo_36:d7:16 (08:00:27:36:d7:16), Dst: [Pvdmcast_00:00:01 (01:00:5e:00:00:01)]
Internet Protocol Version 4, Src: 192.168.1.59 (192.168.1.59), Dst: 239.0.0.1 (239.0.0.1)
User Datagram Protocol, Src Port: 53836, Dst Port: 49152 (49152)
Data (607 bytes)
Data: 3056444d010000005016ee253395ba8e000000700002711...
[Length: 607]

```

0000 01 00 5e 00 00 01 08 00 27 36 d7 16 08 00 45 62  :.....'6....E\
0010 02 7b 00 00 40 00 01 11 e6 31 c0 a8 01 3b ef 00  :...B...1...
0020 00 01 d2 4e c0 00 02 67 54 d3 30 56 44 ad 01 00  :...L...g T.OVDM..
0030 00 00 50 16 0e 00 00 00 0a 0e 00 00 00 07 00 00  :..P..A...
0040 27 11 02 5f 00 01 00 01 00 24 02 3b 00 00 3c 3f  :.....$.i...?
0050 78 64 0e 20 76 05 73 69 0f 0e 3d 31 2e 30  :.....sione1.0
0060 22 2f 3e 0a 2c 76 64 6d 3a 6d 65 73 73 61 67 65  :*?..-vdm: message
0070 73 20 78 64 6e 73 69 65 73 73 69 64 6d 22 68 74  :s xmlns: vdm:chtt
0080 70 3a 2f 77 77 77 7a 76 69 63 74 6f 72 79 2d  :P://www.victory.
0090 73 74 61 6e 64 61 72 64 73 2e 6f 72 67 2f 53 63  :standard s.org/Sc
00a0 68 65 6d 614 3f 32 30 31 31 30 37  :nemas/VDM 4.201102
00b0 32 39 2e 78 73 64 22 20 78 6d 6c 6e 73 3a 70 64  :29.xsd" xmlns:vd
00c0 74 3d 22 69 74 70 3a 2f 77 77 77 7a 76 69 63 65  :t=http://www.vi
00d0 69 74 6f 72 76 2d 73 74 61 6e 64 61 72 64 73 2e  :ctory:et andards.
00e0 6f 72 6f 53 63 68 65 6d 61 73 2f 56 48 43 54  :org/Sche mas/VICT
00f0 4f 52 59 44 61 74 61 64 79 70 65 73 5f 32 30 31  :OVDataT ypes_201
0100 31 30 37 32 39 2e 78 73 64 22 3e 0a 3c 70 6f 73  :10729.xs d"-spos
0110 69 74 69 6f 73 61 6e 4d 6e 73 61 6f 65 20 69 6e 74  :itiones sage int
0120 65 72 66 61 63 65 49 64 3d 22 30 22 20 74 69 6d  :erfaceID ="0" tim
0130 66 74 6d 70 3d 22 3a 32 37 3a 31 37 2e 38 36 35 34  :estamp=" 2012-07
0140 33 30 54 32 30 3a 32 37 3a 31 37 2e 38 36 35 34  :30T20:27 117.8654
0150 39 36 34 30 30 5a 22 20 73 65 71 75 65 6e 63 65  :064002" sequence
0160 48 75 6d 62 65 72 3d 22 37 22 3e 0a 3c 76 64 74  :Number=" ?"-vdm:
0170 3a 6c 61 74 69 74 75 64 65 20 55 73 74 69 6d 61  ::latitud e estima
0180 74 05 64 3d 22 60 61 6e 73 65 22 70 01 6e 69  :ted: false" set_val
0190 64 2d 22 74 72 75 65 22 20 75 6e 63 65 72 74 61  :d="true" uncerta
01a0 69 6e 64 2 74 75 3d 2 3e 30 2e 30 30 30 3c  :inty="0" or="0000s
01b0 2f 76 64 74 3a 6e 61 74 69 74 75 64 65 3e 0a 3c  :/vdt:lat itude>.<
01c0 75 64 74 3a 6f 6e 67 69 74 75 64 65 20 65 73  :vdt:long itude es
01d0 74 69 6d 61 74 65 64 3d 22 66 61 6e 73 65 22 20  :timated=" false"
01e0 76 61 6e 69 64 3d 22 74 72 75 65 22 20 75 6e 63  :valid="t rue" unc
01f0 65 72 74 61 69 6e 74 79 3d 22 30 22 3e 30 2e 30  :ertainty "-or="0.0
0200 30 30 30 3c 2f 76 64 74 3a 6e 6f 6e 67 69 74 75  :000=/vdt :longitu
0210 64 65 3e 0a 3c 76 64 74 3a 61 65 69 74 65 64  :de="vdt :latitud
0220 65 20 65 73 74 69 6d 61 74 65 64 3d 22 66 61 6e  :e estima ted: false"
0230 73 65 72 76 61 72 76 61 72 76 61 72 76 61 72 76  :set_val ity="1" s
  
```

em1: Live capture in progress. Filter: udp.dstport == 49152. Packets: 2948 Displayed: 144 Marked: 0

<?xml version="1.0"?>

<vdm:messages xmlns:vdm=<http://www.victory-standards.org/Schemas/VDM.xsd>

xmlns:vdt=<http://www.victory-standards.org/Schemas/VICTORYDataTypes.xsd>>

<positionMessage timestamp=" 2012-07-31T15:15:44.5080375397Z" sequenceNumber="1" interfaceID="0">

<vdt:latitude valid="true" uncertainty="0" estimated="false">38.898648</vdt:latitude>

<vdt:longitude valid="true" uncertainty="0" estimated="false">-77.037692</ vdt:longitude>

<vdt:altitude valid="false">0</ vdt:altitude>

<MGRS> 4QFJ1234567890</MGRS>

</positionMessage>

</vdm:messages>

</xml>

Position Service Benchmarking

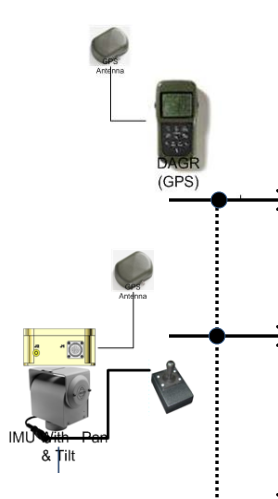


- (1) **Each VICTORY process' system and (2) memory utilization**
 - Average CPU Utilization: 1.053%
 - Average Memory Consumption: 0.772%
 - Average System Jiffies: 0.666
 - Minimum CPU Utilization: 0%
 - Maximum CPU Utilization: 3.061%
- (3) **Processing Time of VDMs**
 - XML Build Time Average. BeagleBoard: 713,100 nsec vs. Workstation Build Time: 83,000 nsec
 - VDM Transmit Time Average. BeagleBoard 953,000 nsec vs. Workstation: 100,000 nsec



Additional Overhead on System For Each Sensor Type

Comparison of overhead from VICTORY software versus the external sensors / peripherals

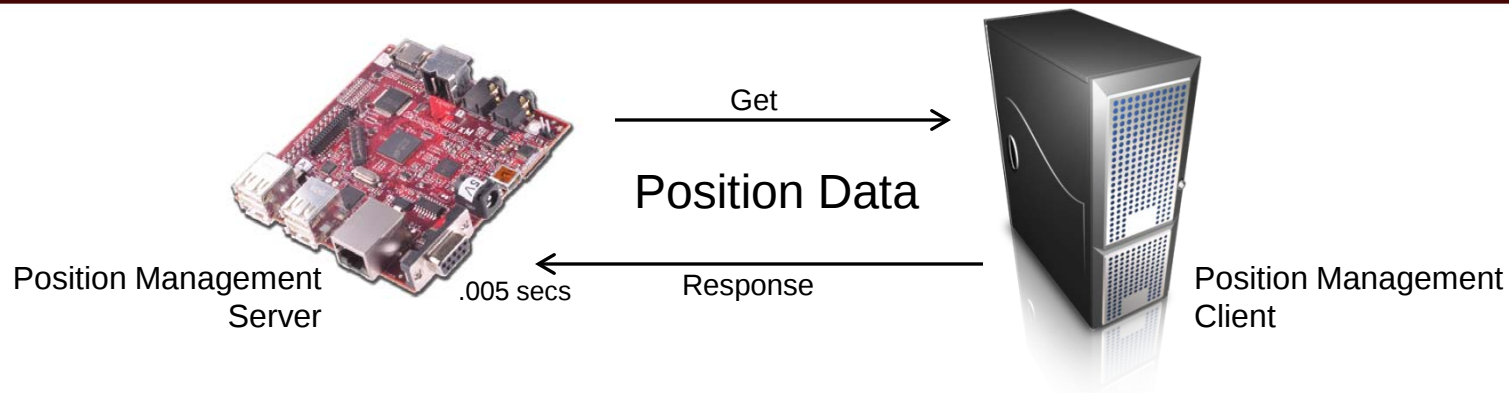


Device	Service	Average CPU Utilization	Average Process Jiffies
GPS Sensor	Position	1.053%	.666
Synthetic GPS Data	Position	.375%	.388
INS Sensor	Orientation	.433%	.665
Synthetic INS Data	Orientation	.395%	.388
Obtained via Position & Orientation Data	Direction of Travel	.531%	.659
Synthetic Direction of Travel Data	Direction of Travel	.404%	.388

When running VICTORY services that consume sensor data, it is found that each sensor accounts for 64.3%, 8.7%, and 23.9% of the process execution, respectively for each service. Running at 4800 Baud, the receive, process, and transmit states for the serial GPS device are the largest bottleneck in terms of sensor/system performance.

GSOAP Service Model Efficiency

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Frequency	% Average CPU Utilization	# of dropped Ethernet packets
1 Hz	.54	0
10 Hz	2.77	0
100 Hz	25.22	0
200 Hz	49.14	0

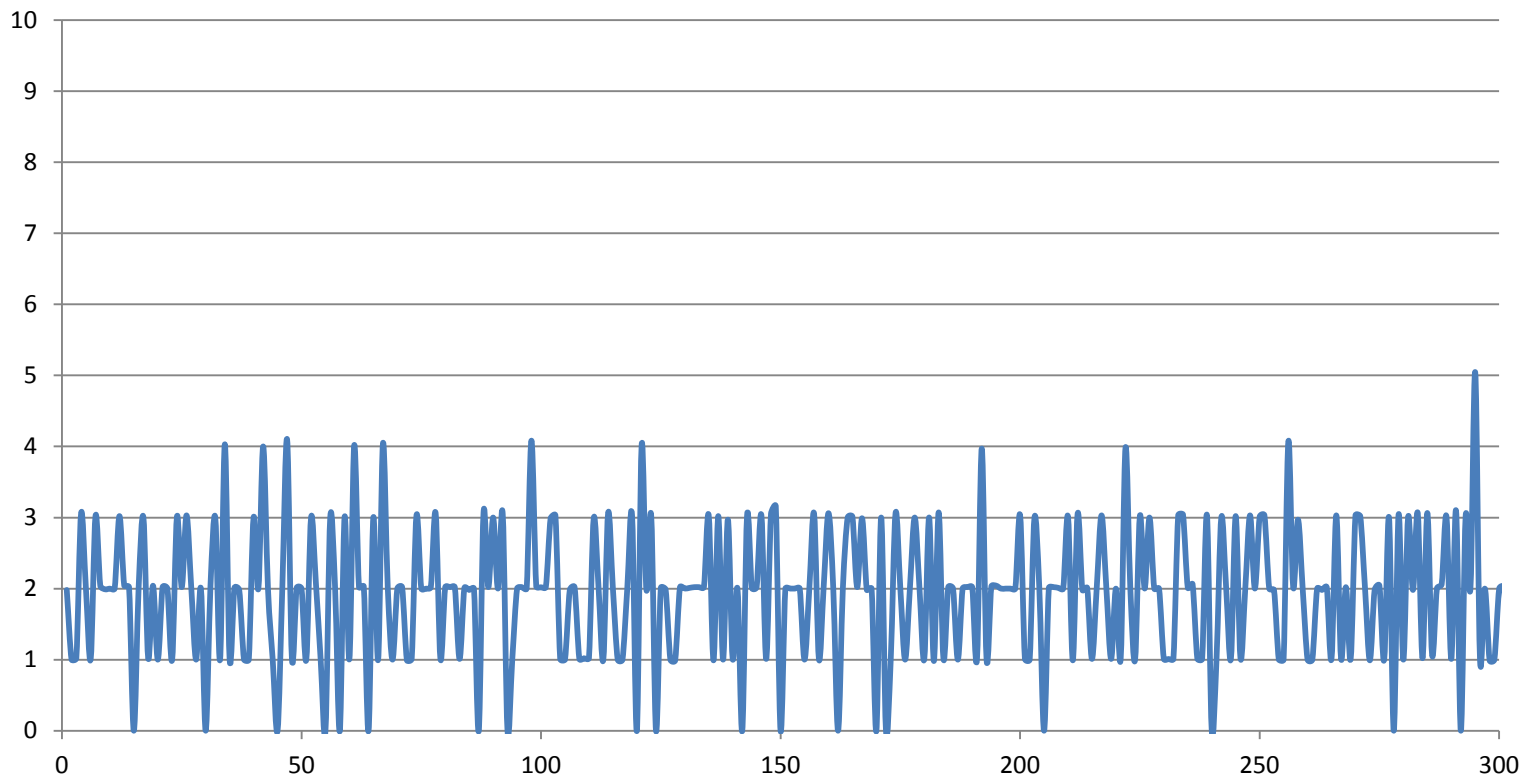


Aggregation of the Core VICTORY Services in Execution

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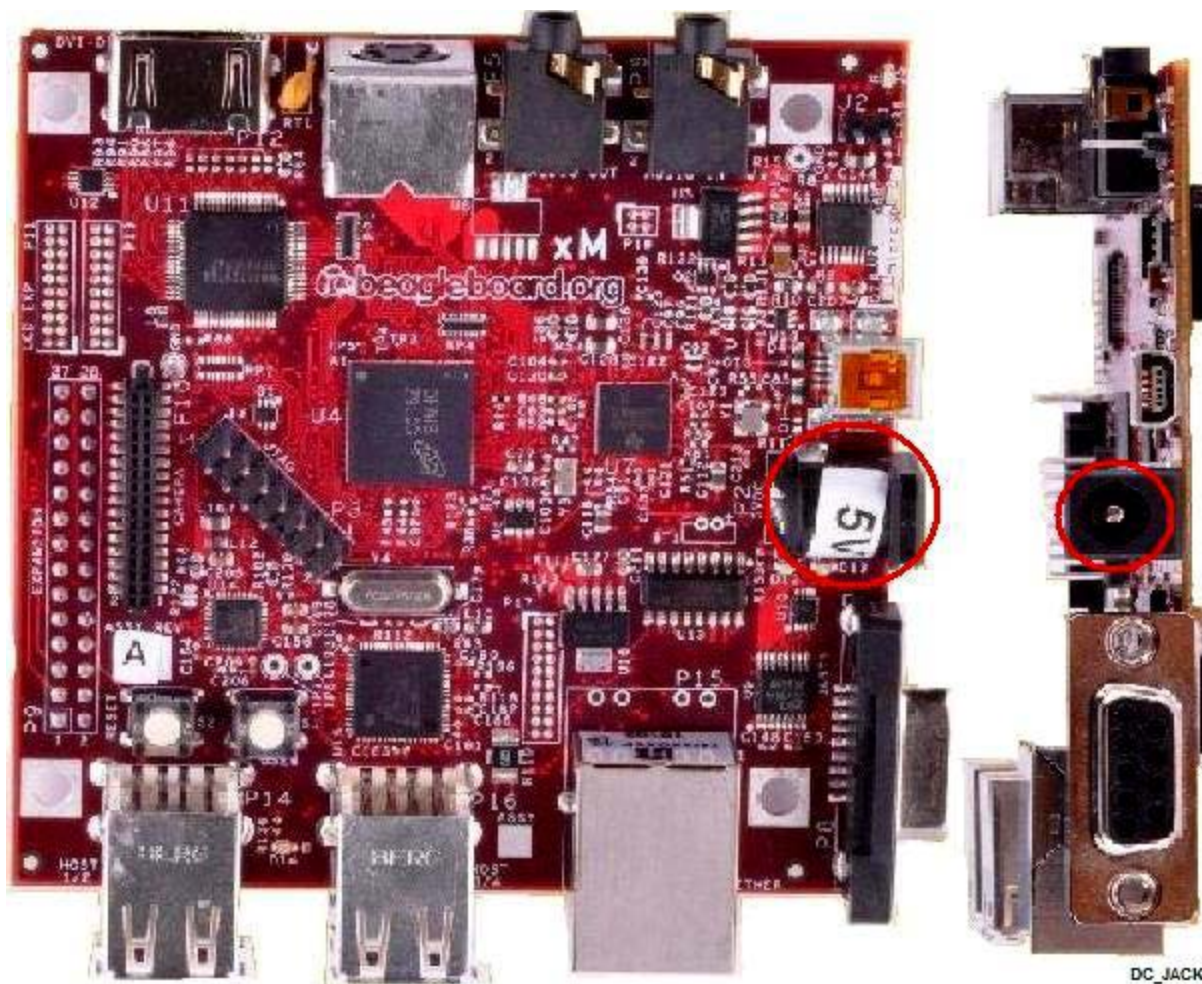
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Percent CPU Utilization of all Services in Execution (per second)



Measuring Power Consumption

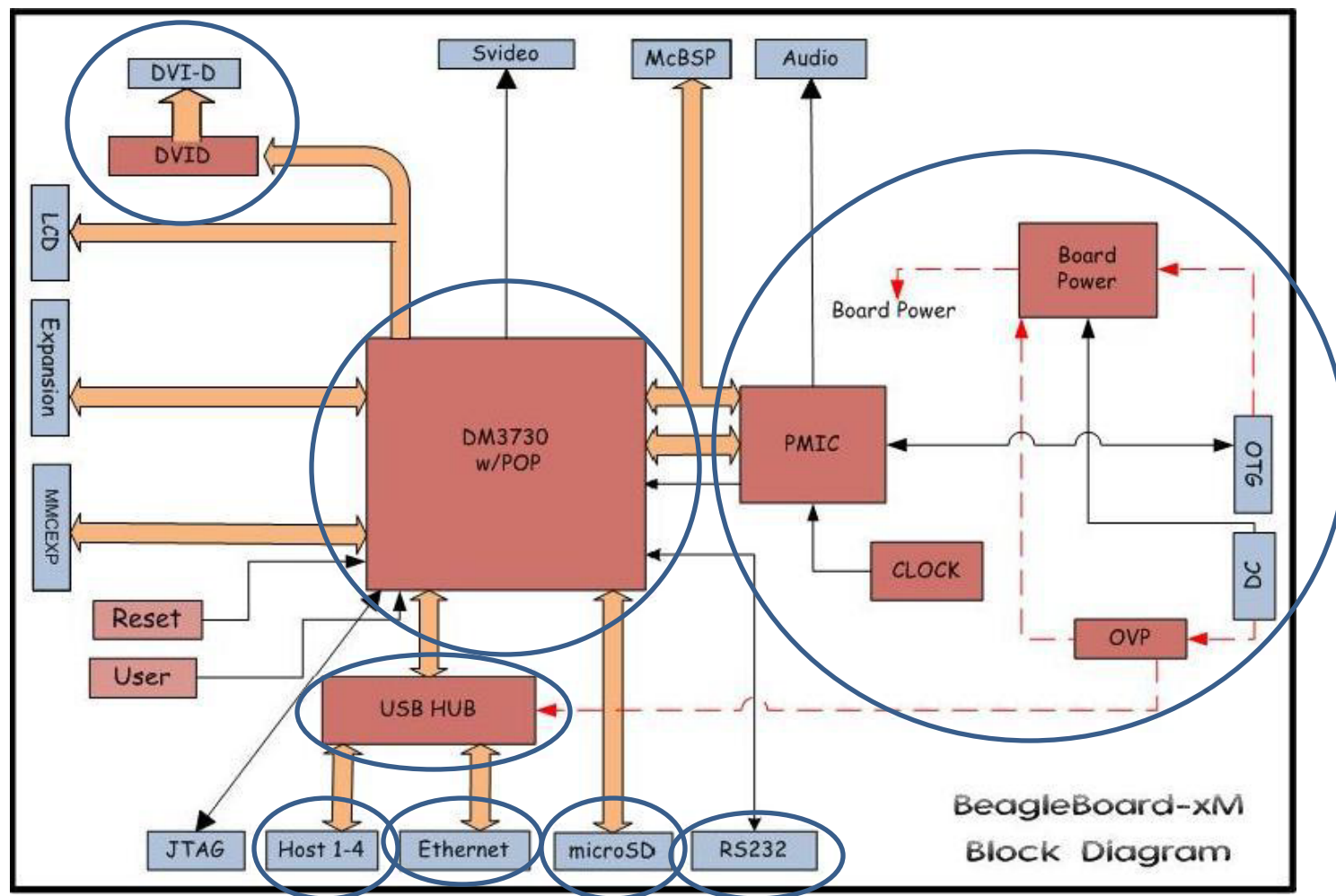
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- Tektronix DPO 4104 Oscilloscope - used to collect and store data on current draw from current probe and amplifier.
- Tektronix 6302 Current Probe - non-invasive probe for measuring electrical current through a wire.
- We used this hardware to collect the power consumption during system execution.

High Level Block Diagram of Components Under Test

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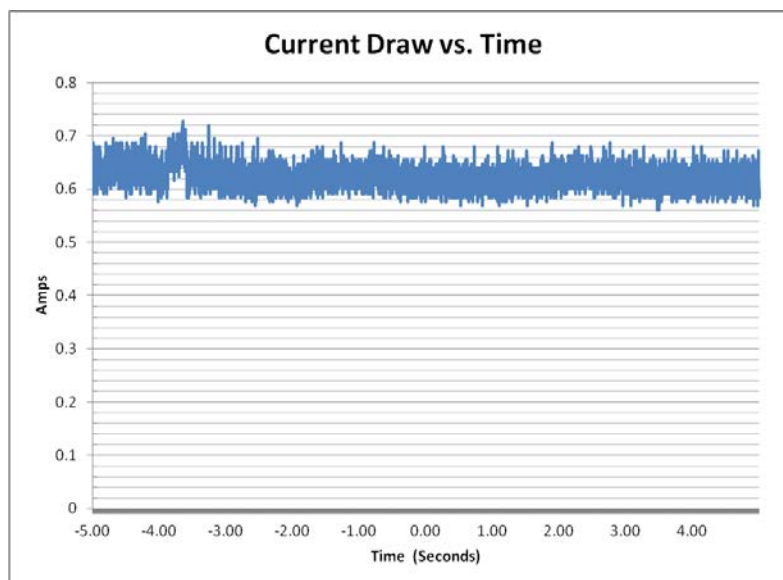


Power Draw of BeagleBoard in Operation



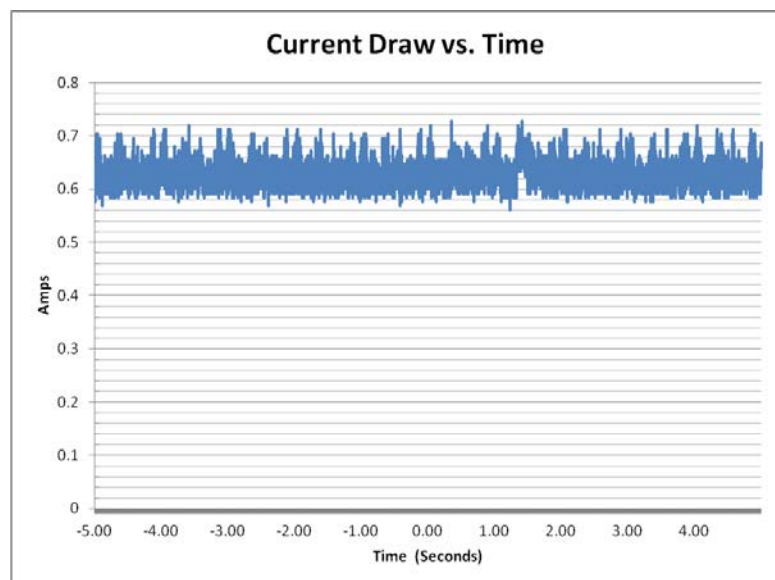
Measurements taken while running Ubuntu OS (executing a 2.6 Linux kernel) and running a stripped-down X-windows GUI that was being driven to an LCD display.

Stable average of 0.62 Amps / 3.10 Watts



**Current Draw (Amps) -
VICTORY Services at Rest**

Stable average of 0.64 Amps / 3.2 Watts



**Current Draw (Amps) with
VICTORY Services in Operation**

Power Draw Comparison



BeagleBoard xM

3.2 Watts



Dell Workstation PCs
running 6-cores:

72.12 Watts

95.6% more efficient

The same tests were executed while running the same VICTORY services on Dell Workstation PC; this resulted in an observed 0.85 Amps RMS. This consequently computes to a total average power consumption of 72.12 Watts. Thus, the magnitude of 72.12 Watts versus the 3.15 Watts measured on the BeagleBoard represents a savings of 68.97 Watts, and is 95.6% more efficiently to run the very same services.

Summary



- Executing multiple VICTORY data services, and reading multiple VICTORY-compliant sensors at the same time resulted in the following performance measurements for the system:
 - 0.64 Amps / 3.15 Watts Power Consumption at run-time.
 - Roughly 0.77% System Memory Utilization per Service
 - 1.05%, 0.433%, 0.531% average CPU utilization for Position, Direction of Travel, and Orientation Services, respectively.
 - Less than 1.7 milliseconds processing time (Building and Publishing Full Featured VICTORY XML Messages).
 - A delta of 68.97 Watts between workstation and BeagleBoard, which is 95.6% more efficient.
- Therefore, boards based on this type of architecture are an excellent candidate for running VICTORY services while providing significant reductions in SWAP-C for the VICTORY 1.0 project.



Final Thoughts

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? Questions ?

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