2010 ECE CAPSTONE

Portland State Aerospace Society
Portland State University

Team Member:

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PSAS Advisor: Andrew Greenberg

Sponsor: Portland State Aerospace Society

PSAS Avionics System Rev. 2b (AV2b)

PORTLAND STATE AEROSPACE SOCIETY

Umbilical Cord
19V shore power
Launch relay interlock

Inertial Measurement Unit
X axis Linear Accelerometer
Y axis Linear Accelerometer
Z axis Linear Accelerometer
Pitch Rate Gyroscope
Yaw Rate Gyroscope
Roll Rate Gyroscope
Temperature
Maxim MAX1168 16bit ADC
8 channels, 200ksps
SPI
Philips LPC2148 Microcontroller
60MHz 32 bit ARM uC with USB running eCos

Avionics Power System
16.8V 4Ah Battery Pack
4S4P pack of 4.2V 1Ah Lithium ion Batteries
Power System Board
Smart battery charging and monitoring
MOSFET power switches to subsystems
Philips LPC2148 Microcontroller
60MHz 32 bit ARM uC with USB running eCos

Flight Computer
PowerPC Flight Computer
400MHz MPC5200 (603e core) w/128MB SDRAM, 32MB flash, CAN, ethernet, and USB running Debian Linux 2.6.x
Debug (Ethernet, UART0, JTAG)
USB1
USB hub
USB0
USB hub

Universal Serial Bus (USB v1.1)

Telemetry
USB to IEEE 802.11b Adapter
Lucent Orinoco Chipset running on Channel 1
2.4GHz Bidirectional Power Amplifier
YFI Inc +16dB Transmit, +9dB Receive
1 GB USB flash disk

Amateur TV
Philips LPC2148 Microcontroller
60MHz 32 bit ARM uC with USB running eCos
UART
Color Camera
NTSC, Audio out
Video Overlay Board
NTSC + Serial text in; NTSC out
1.253GHz FM Amateur TV Transmitter
15mW output
1.25GHz Class C Power Amplifier
3W output

GPS
Philips LPC2148 Microcontroller
60MHz 32 bit ARM uC with USB running eCos
UART
GPL-GPS Open Source GPS Receiver
12-channel COTS board with OSS firmware
1.575GHz Low Noise Preamp
GPS Source +30dB preamp with SAW filters

Recovery
Philips LPC2148 Microcontroller
60MHz 32 bit ARM uC with USB running eCos
Back up Power
4.1V Lithium ion battery backup
Pyrotechnic System
100V switching supply with MOSFET switches
Drogue Igniter
Main Chute Igniter

LV2 FLIGHT COMPUTER CARRIER BOARD

What's a flight computer ?

The flight computer is the central computer that controls the rocket. It's a single board computer (SBC)

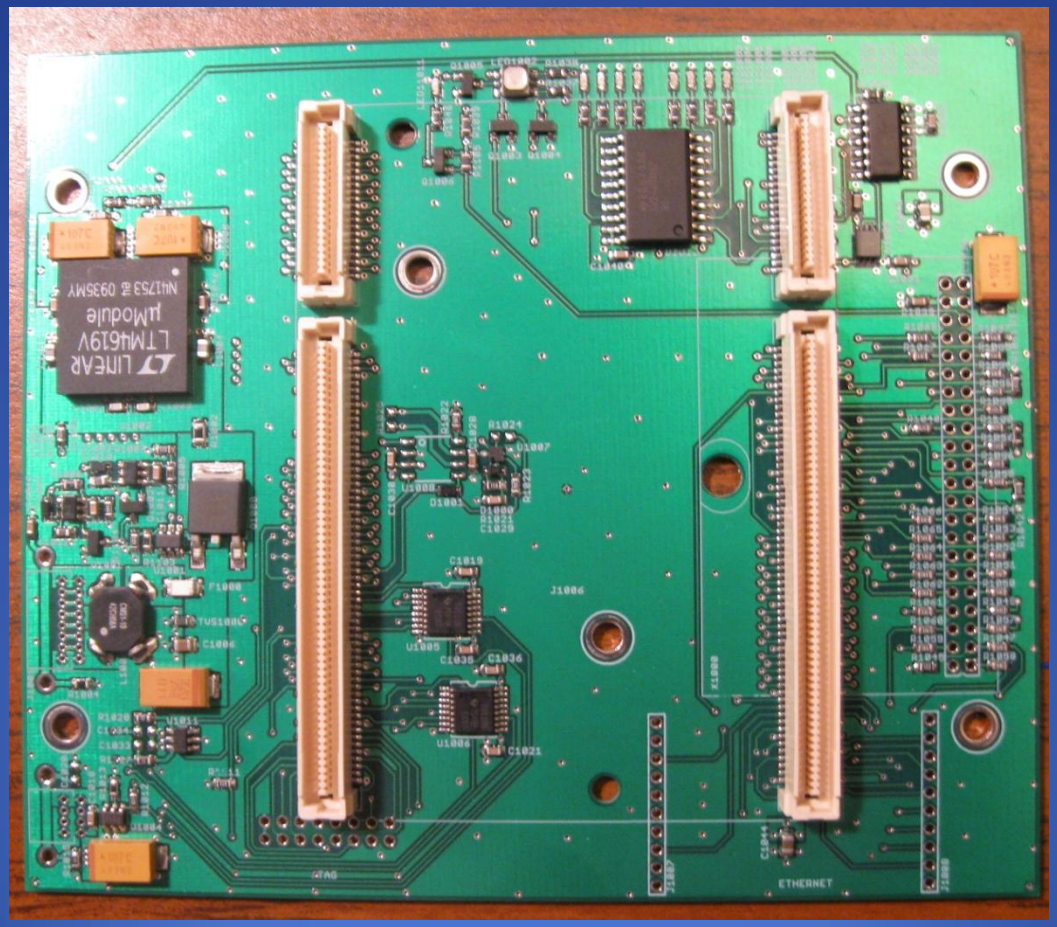
The Flight Computer :

Pros:

The current single board computer (SBC) is a Freescale MPS5200 that runs Linux and communicates to other avionics systems using USB and the Controller Area Network (CAN). It was chosen because it combined a high performance 400 MHz PowerPC core with many peripherals, including 64 MB SDRAM, 32 MB FLASH, USB 1.1, CAN, UARTS, PCI, ATA/IDE, SPI, and more. The SBC uses high density surface mount connectors on the bottom of the board to connect to the rest of the system.

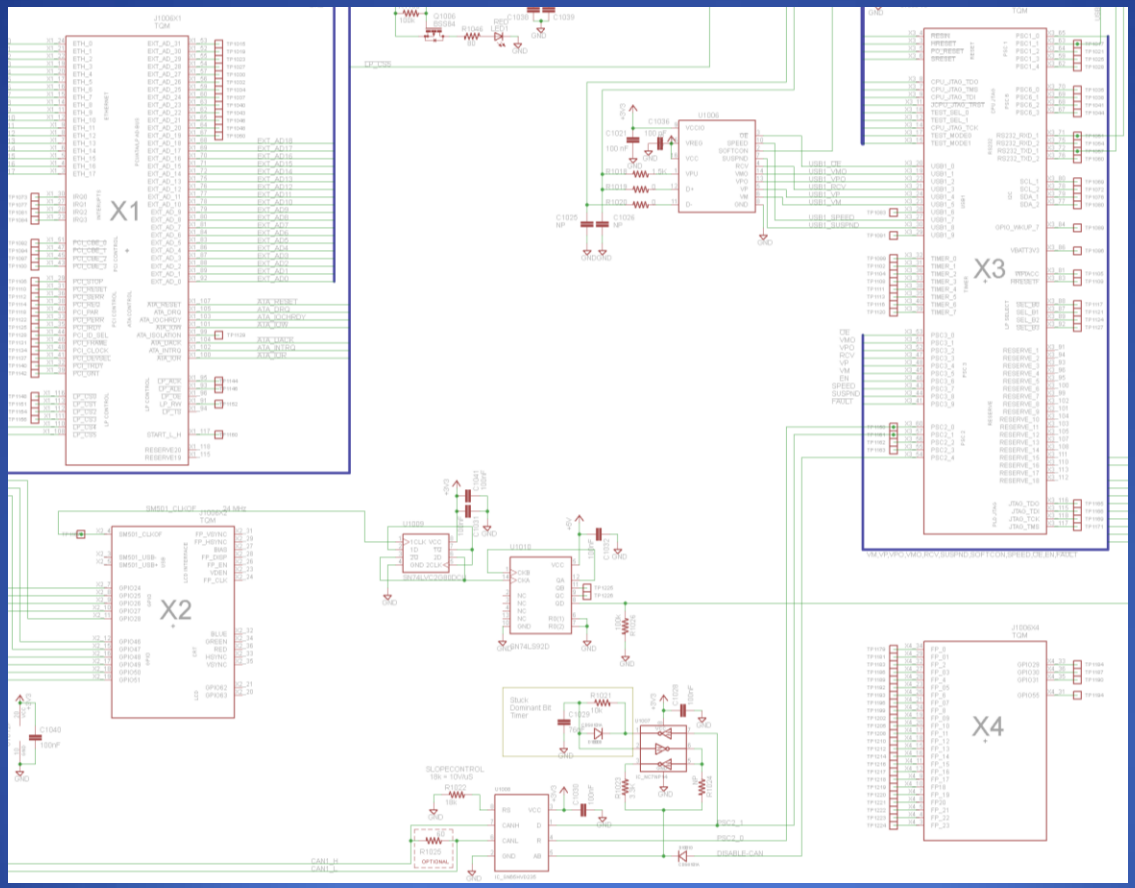
The Flight Computer (Cont…) :

Cons: While a commercial "motherboard" is available to mount the SBC on, it is too large and fragile to use in the rocket.

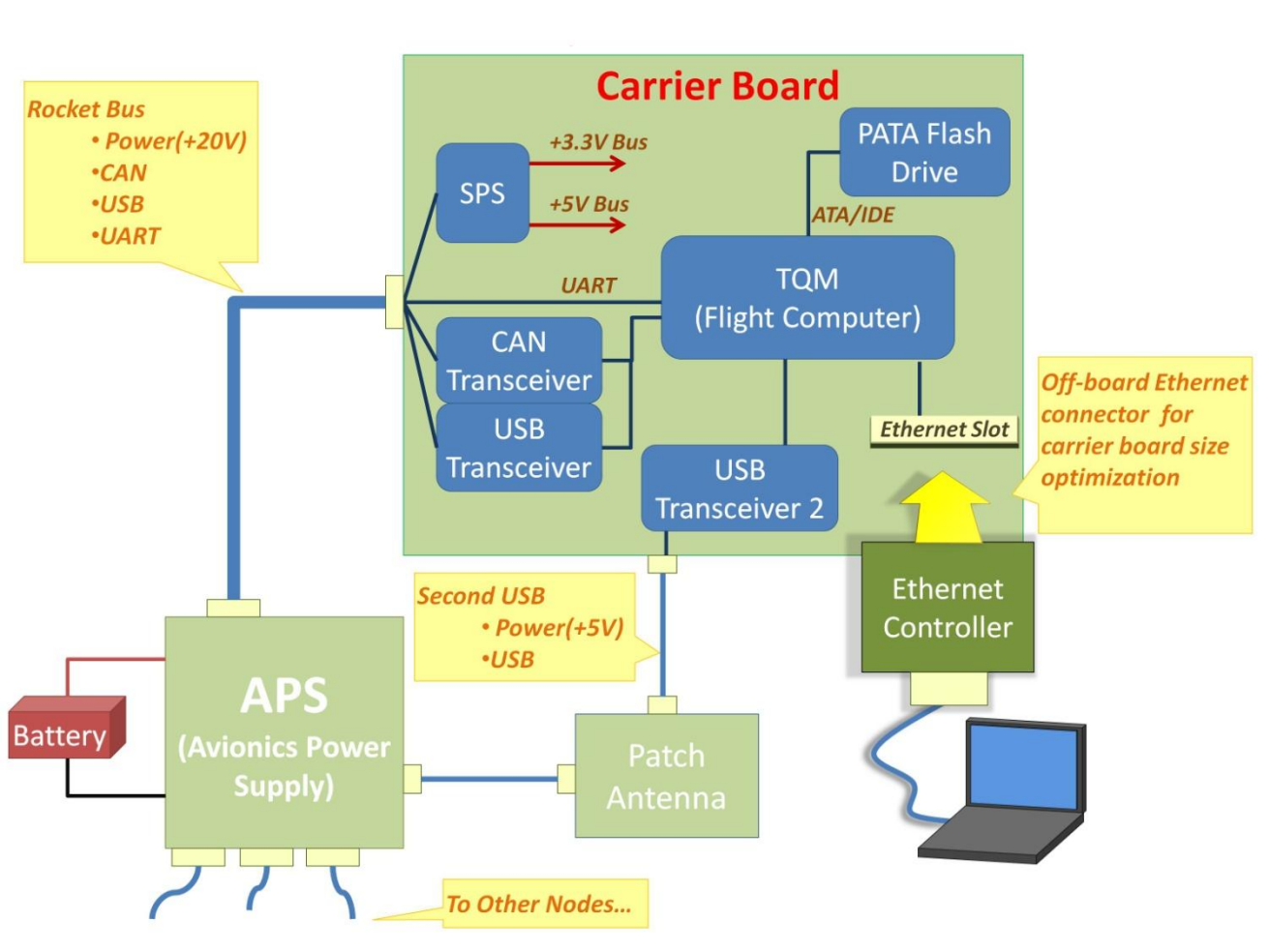


Design objectives:

Our project is to design, build and test a small, robust carrier board for the current Single Board Carrier, the TQ Inc. TQM5200 SBC



LV2 Block Diagram



Design Requirements:

Functionality , performance ,reliability, cost and size :

Telemetry connector:

Must provide a secondary USB 2.0 full speed electrical connection (data and power) to the 802.11a USB adapter

Must be able to turn the USB power on and off from MPC5200

May have some indication of power on/off, data transfer

IDE Connector:

Must securely retain storage card without data loss at (10,20,) g's of force at hundreds of Hz

May have fastener to hold connector to PCB

Must handle (1,8,) GB of storage

Must support the fastest MPC5200 ATA interface, UDMA mode 2 (33 MB/s)
Should be easily removable when not in flight mode; Must have a locked down flight mode

Should be as small and lightweight as possible

May give visual indication for power, reads, and write

Design Requirements (Cont...):

Power Supply:

Must take an input voltage of (10,14.7,20) V.
Must provide 3.3V +/- (,1,5)% for the TQM5200 and CF card.
Must provide 5.0V +/- (,5,10)% for the USB 802.11a adapter.
Must provide enough current, by at least a factor of 120%.
3.3V: 2.2 A * 120% = 2.64A so (2.64,3,) A.
5.0V: 500mA as per USB 2.0 specification so (0.5,1,) A.
Must have a small footprint <= 9 cm&2.
Must be thin, <= 1 cm.
Must be light weight
Must be able to survive (10,20,) g load.
Must be > 70% efficient under all operating loads.
Should have undervoltage cutoff and overcurrent cutoff (foldback is OK).
May have reverse polarity protection; if not, we'll provide it

Design Requirements (Cont…):

Other features:

Must have transceivers as required: CAN, Ethernet, etc.
Must have ESD suppression on all non-power pins.
Should provide 3.3V primary lithium battery for MPC5200 RTC.
Should have at least 8 LEDs and one RGB LED to indication rocket status.
Should have all GPIO available for use via a breakout connector.
If there's an audio out: Should have a small speaker for generating low quality (< 10 KHz BW) tones/voice.
Should breakout VGA, I2C, JTAG and SPI to breakout connectors (VGA needs a corresponding breakout connector to VGA cable).
May have an Ethernet breakout connector (and a corresponding breakout connector to Ethernet cable).Ethernet breakout should include physical layer chips as necessary (e.g., magnetic)

Cost:
Should cost (,150,500) $
Should be a (2,4)layer PCB

Size:
Must be fit in the rocket (ID of ~ 13.33 cm)Must have a width of < 10.6 cm
Should be as small as possible, (48,100,150) cm^2
Should have components on both sides of PCB

Team member Responsibilities:

Pierre: USB interface
CAN interface
Ethernet Connector
IDE Connector

Takuya: Switching Power Supply

Varun: TQM5200
Layout board

USB Interface:

Two USB 1.1 full speed interfaces are used by the FC to communicate high speed data with the rest of the rocket. One USB interface is attached to the rocket's 802.11a-based amateur radio telemetry system, and the other interface attaches to the rest of the avionics system which includes such sensors as a six degree of freedom Inertial Measurement Unit, a GPS receiver, a smart battery pack.

Components:

2 Texas Instrument TUSB1106PWR USB transceiver

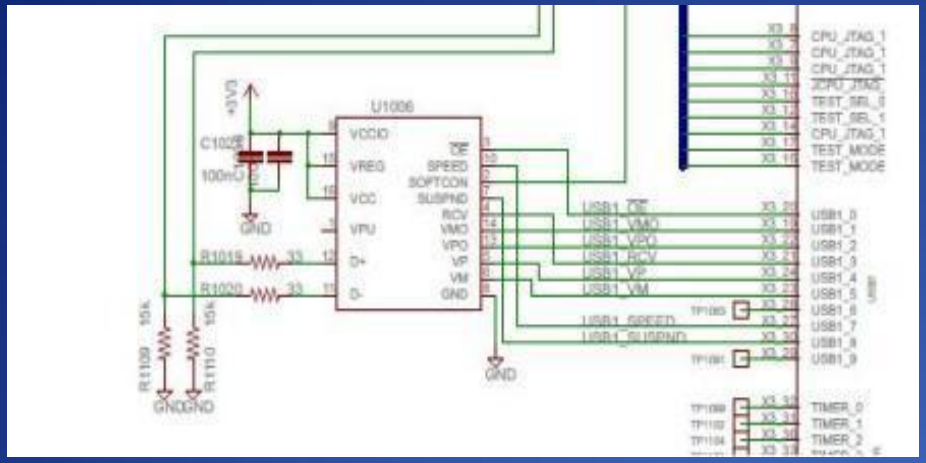
- Availability on Digikey at about $8.93 a piece
- Unambiguous implementation (no additonal configuration needed for differential mode data transfer.)
- Supports USB 2.0 protocol
- relatively small size: 16-TSSOP
- Operate with a 5V or 3.3V supply (internal regulator)

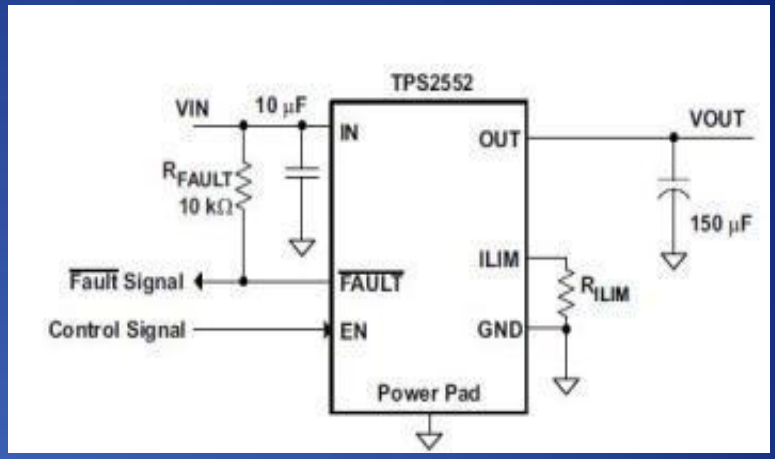
1 Texas Instrument TPS2552 Adjustable Current-Limited Power-Distribution Switch

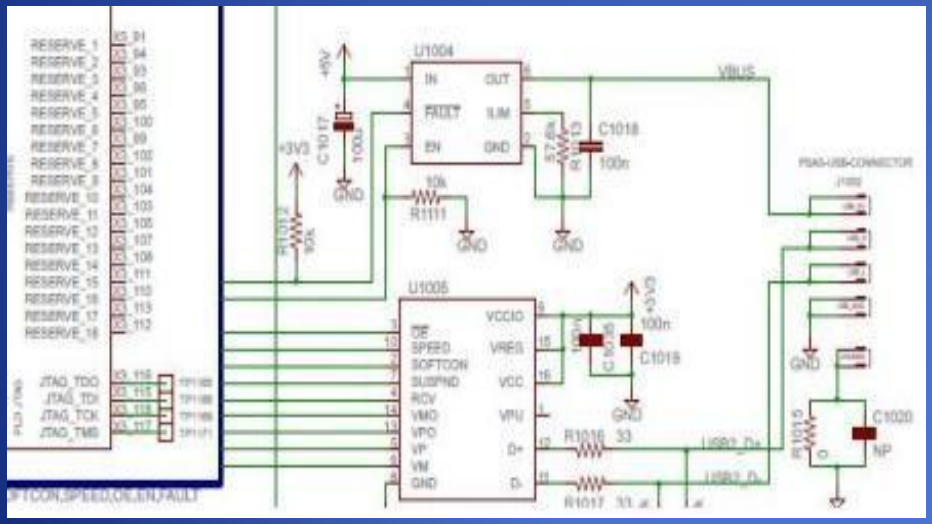
- Availability on Digikey at $9.98 a piece
- Come in small size package: SOT-23-6
- Voltage operation: 2.5 ~ 6.5 V
- Programmable current threshold for over current protection set by Rilim
- Reverse voltage protection(turn off n-channel mosfet when Vout>135mV)
- Fault response asserted during overcurrent, overtemperature

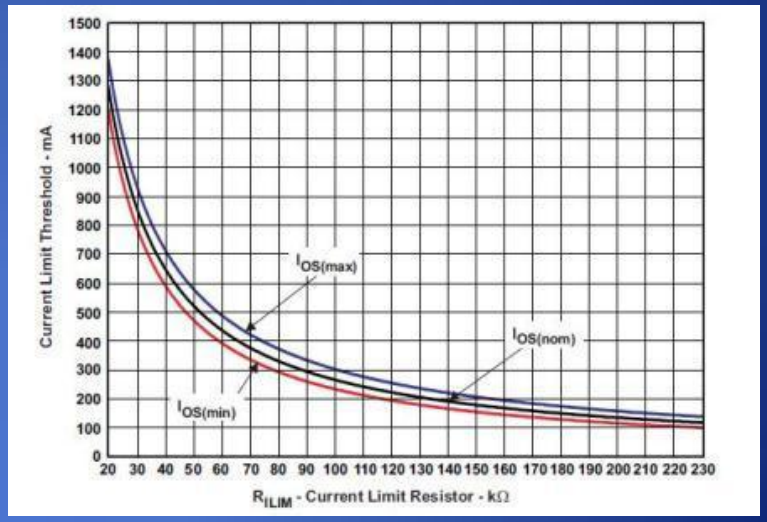
USB Interface (Cont…):

Schematics









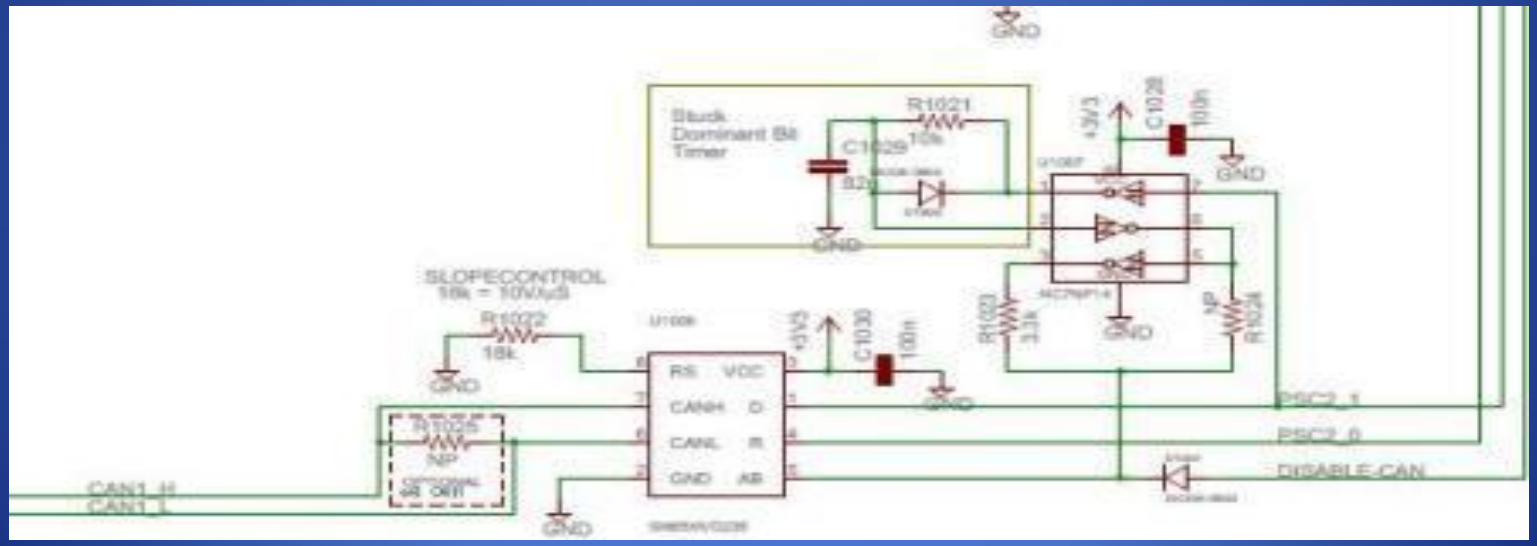
CAN interface:

The Controller Area Network (CAN) is used to meet the need for a highly reliable safety system and communication bus between the nodes of the avionics system. The peer to peer bus topology of CANs is useful in case of a flight computer failure

Components:

1 Texas Instruments CAN transceiver (part#: SN65HVD235)

- Availability on Digikey at $4.34
- Small size package: SIOC
- Voltage operation: 3-3.6V
- Because CAN interface was successfully used in prior Capstone, the sponsor recommended us to use the already available design.



IDE connector:

A 44 pin IDE Flash Module provides a reliable storage device that meets the challenges of a hostile environment, limited space, and low weight. It is compatible with Standard IDE ATA interface and supports UDMA data transfer modes

Components:

Disk On Module (DOM):

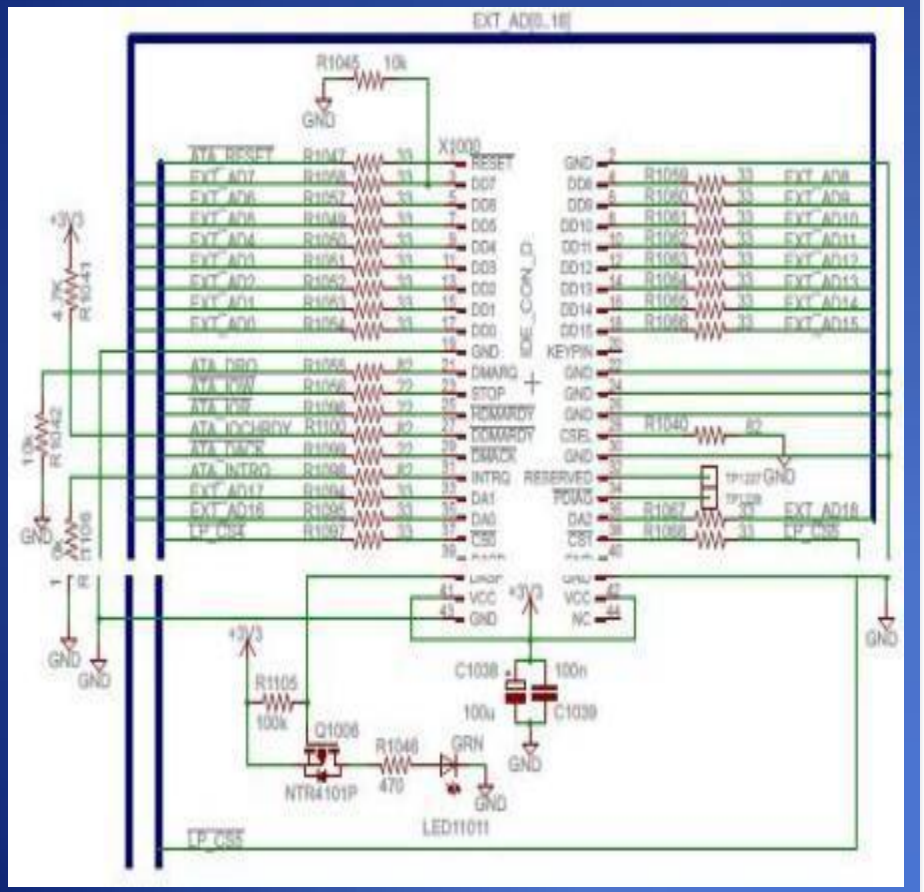
Interface: 44pin IDE/ATA
IDE Transfer Mode: PIO mode 0-4/UDMA mode 0-4
Vibration: 5G(7~2000Hz)
Shock: 50G/10ms
Read/Write : 80/75Mbs
DC Input Voltage: 3.3V-5V

A 44-Pin embedded disk card:

Locked housing design for stability
Vibration support
Low Power Consumption: 150mA
DC Input Voltage: +3.3V/+5V Single power supply operation
Windows XP embedded and Linux bootable

IDE connector (Cont…):

Schematics and table:



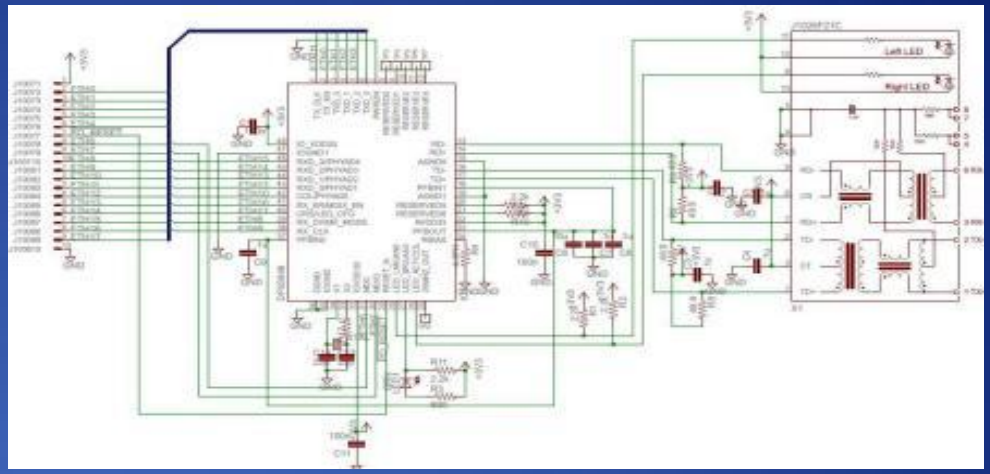
ATA TQM pinouts

44 Pin #	ATA-4 PIN NAME	ATA-4 HOST CONNECTION	Host <> Device	STK sheet # name	TQM name	PCB requirements
1	RESET-	-		IDE_RESET-	ATA_RESET	
2	Ground	GND		GND		
3	DD7	-	<> *	IDE5V_DD7 (10K pulldown)	EXT_AD7	10K pulldown
4	DD8	-	<> *	IDE5V_DD8	EXT_AD8	
5	DD6	-	<> *	IDE5V_DD6	EXT_AD6	
6	DD9	-	<> *	IDE5V_DD9	EXT_AD9	
7	DD5	-	<> *	IDE5V_DD5	EXT_AD5	
8	DD10	-	<> *	IDE5V_DD10	EXT_AD10	
9	DD4	-	<> *	IDE5V_DD4	EXT_AD4	
10	DD11	-	<> *	IDE5V_DD11	EXT_AD11	
11	DD3	-	<> *	IDE5V_DD3	EXT_AD3	
12	DD12	-	<> *	IDE5V_DD12	EXT_AD12	
13	DD2	-	<> *	IDE5V_DD2	EXT_AD2	
14	DD13	-	<> *	IDE5V_DD13	EXT_AD13	
15	DD1	-	<> *	IDE5V_DD1	EXT_AD1	
16	DD14	-	<> *	IDE5V_DD14	EXT_AD14	
17	DD0	-	<> *	IDE5V_DD0	EXT_AD0	
18	DD15	-	<> *	IDE5V_DD15	EXT_AD15	
19	Ground	GND		GND		
20	(keypin)	NC		NC (key pin)		
21	DMARQ	-	<	IDE5V_DMAREQ	ATA_DRQ	10K pulldown
22	Ground	GND		GND		
23	DIOW-,STOP	-		IDE5V_IOW	!ATA_IOW	
24	Ground	GND		GND		
25	HDMARDY-	-		IDE5V_IOR		!ATA_IOR
26	Ground	GND		GND		
27	DDMARDY-	-	<	IDE5V_IOCHDRY	ATA_IOCHDRY	IE pullup to 5V
28	CSEL	GND		Slave Master (330 pulldown)		330 pulldown
29	DMACK-	-		IDE5V_DACK	!ATA_DACK	
30	Ground	GND		GND		
31	INTRQ	-	<	IDE5V_INTRQ	ATA_INTRQ -	
32	reserved	NC		NC (NP 089 to IDE5V_D16)		
33	DA1	-		IDE5V_DA1	EXT_AD17	
34	PDIAG-	NC		IDE5V_DIAG	NC	47n cap
35	DA0	-		IDE5V_DA0	EXT_AD16	
36	DA2	-		IDE5V_DA2	EXT_AD18	
37	CS0-	-		IDE5V_CS0	LP_CS4	
38	CS1-	-		IDE5V_CS1	LP_CS5	
39	DASP-	NC		IDE_3DACT (also to FLACT)	NC	
40	Ground	GND		GND		
41	VCC - Logic	VCC		VCC_5VP		100u + 100n bypass
42	VCC - Motor	VCC		VCC_5VP		100u + 100n bypass
43	GND	GND		GND		
44	NC	NC		NC		

Ethernet Connector:

The Ethernet connection provides a direct, high speed debugging and testing interface. While not used during flight, it is used while developing cod

Components

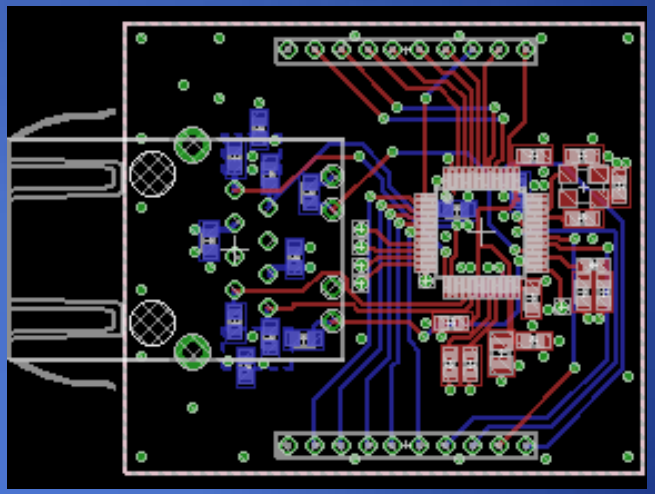


Ethernet Transceiver

Part #: DP83848C
Unit Price: $6.8 on Digikey
Package: 48-LQFP
DC Input Voltage: 3V~3.6V

RJ45

Part #: J1026F21CNL
Unit Price: $6.59 on Digikey
Package: Panel Mount; Through Hole, R. Angle
Speed: 10/100 Base-TX
LED Color: Yellow - Green



Crystal Oscillator

Part #: ECS-250-20-33-TR
Unit Price: $3.57 on Digikey
Frequency: 25Mhz
Mounting Type: Surface mount

Switching Power Supply:

The Switching power supply (SPS) module takes 20V input from the rocket's power distribution bus and converts to 3.3V and 5V in order to run all of the components on the FC carrier. The SPS node is synchronized with a 500kHz crystal-controlled clock for noise shaping. The SPS includes active protection circuitry with automatic recovery capability from hazardous conditions such as over-voltage,
under-voltage, reverse voltage, and even SPS failure (passing unregulated voltage through

Components:

LTM4619 (Dual, 26VIN, 4A DC/DC µModule Regulator):

This is SPS which creates 5V and 3.3V output from 10-20V input. This component was chosen because of high current output (4A) and simplicity of design. It has inductors in the module thus we do not need to design whole buck converter. SPS is synchronized with external clock of 500kHz from the 24MHz oscillator on TQM5200. 24MHz signal is divided down to 500kHz through U1009 and U1010. Its' input current and output voltage is protected by Q1000. 500kHz of external was chosen because it is easier to be generated from 24MHz oscillator using frequency divider.

MAX5902AAETT (+72V SOT23 Simple Swapper Hot-Swap Controller):

This hot-swap controller IC serves two purposes: (1) circuit-breaker and (2) UVLO protection. This controller turns off Q1000 under several conditions. (1) if there is under voltage at the input, (2) if there is overcurrent, (3) if the die temperature exceeds +125 C (4) if SPS-5V output exceeds 5.46V and (5) if SPS-3.3V output exceeds 3.6V.

(1) Under voltage protection threshold is set to be 9V by voltage divider R1103 and R1104.
(2) Over current threshold of 1.62A is set by series resistance of R1002 and RDS(on) of Q1000.
(4) Overvoltage protection of SPS-5V is sensed by U1003 and toggled by Q1001.
(5) Overvoltage protection of SPS-3.3V is sensed by U1002 and toggled by Q1002.

Switching Power Supply (cont…):

TLV3012AIDBVT (Comparator with Voltage Reference)

U1003 watches overvoltage on SPS-5V output. In the event SPS-5V output exceeds 5.46V, it turns on Q1001 and makes pin2 (Drain) of U1001 close to GND, then U1001 shuts Q1000 off: SPS is disconnected from power bus. See capstone 2009 [LV2C:GFE:U2251]

SN74LVC2G80DCU (Dual positive-edge-triggered D-type Flop-flop)

: This D-type flip-flops divide 24MHz clock signal from TQM5200 by 4, and it is cascaded to U1010 (SN74LS92D: divide by 12 counter) to finally create 500kHz clock. Since we did not know output voltage levels of 24MHz oscillator on TQM5200, and to ensure this clock drives flip-flops, we had to use the same supply voltage (3.3V) for this component. Output voltage level (Running at 3.3V supply) of this component also had to meet input voltage levels of U1010 (SN74LS92D: divide by 12 counter

SN74LS92D (Divide-by-12)

This component is divide-by-12 counter cascaded from divide-by-4 flip-flops. In order to generate 500kHz clock from 24MHz clock it has to be divided 48. However there were no such a single chip divider thus we cascaded divide-by-4 and 12. It has 2V of logic high minimum input voltage it is within output voltage level of divide-by-4 flip-flops, and it has high-level output voltage 2.4V (minimum) which is high enough to drive UXXXX (LTM4619). This divider outputs clock signal with duty ratio of 50%. Pull-down resistor on the pin QD pulls to logic low while starting up the board and it enable UXXXX (LTM4619) force continuous operation until UXXXX receive 500kHz clock signal.

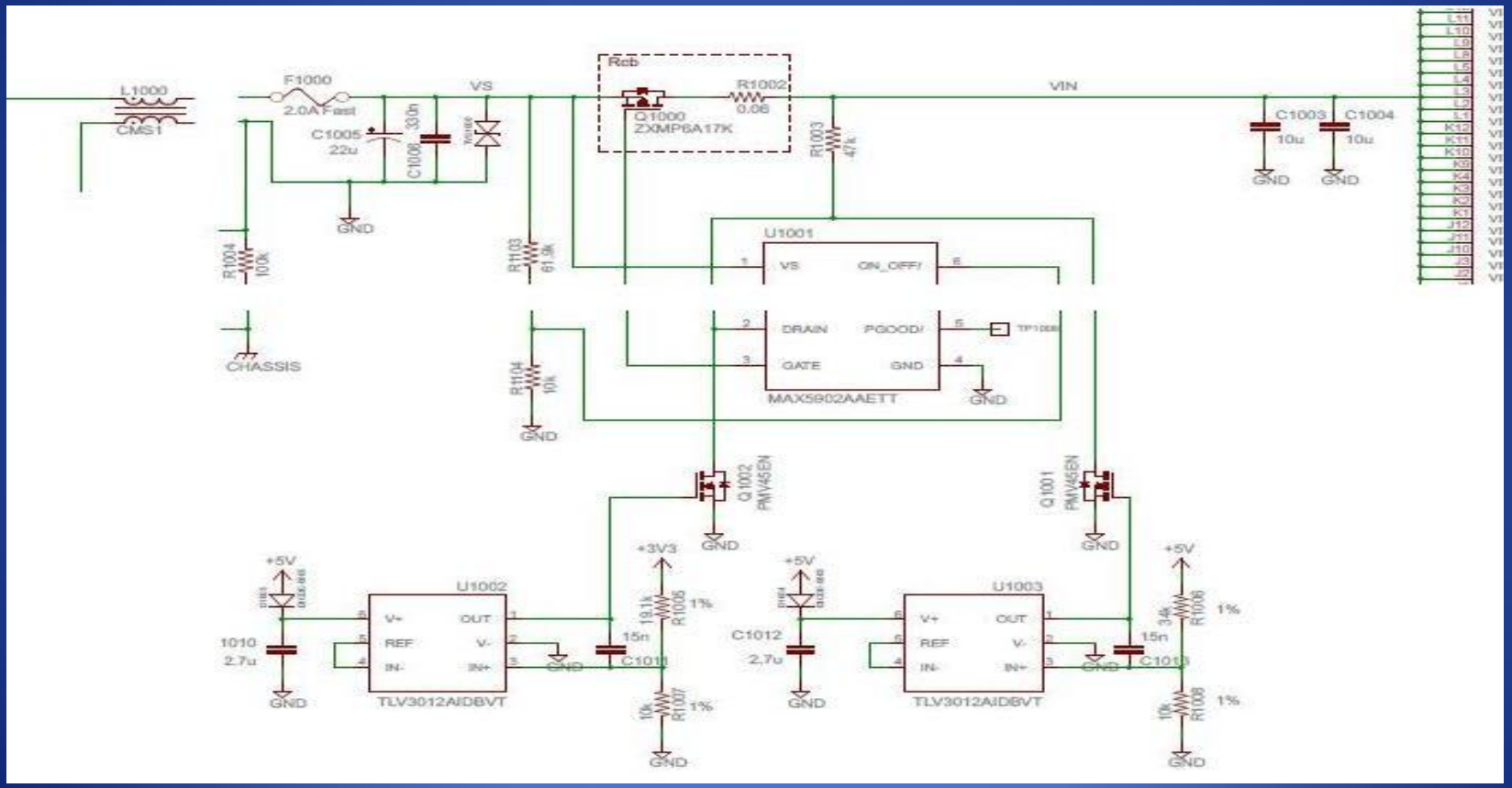
Switching Power Supply (cont…):

Power Bus input Choke

Common mode choke (balanced inductor). It is used as an EMI filter between the power bus and the SPS. he capstone 2006 value was chosen through a trial and error process from the previous LV2 SPS design. Each inductor of the choke is 100 uH.

Node Power Supply Fuse

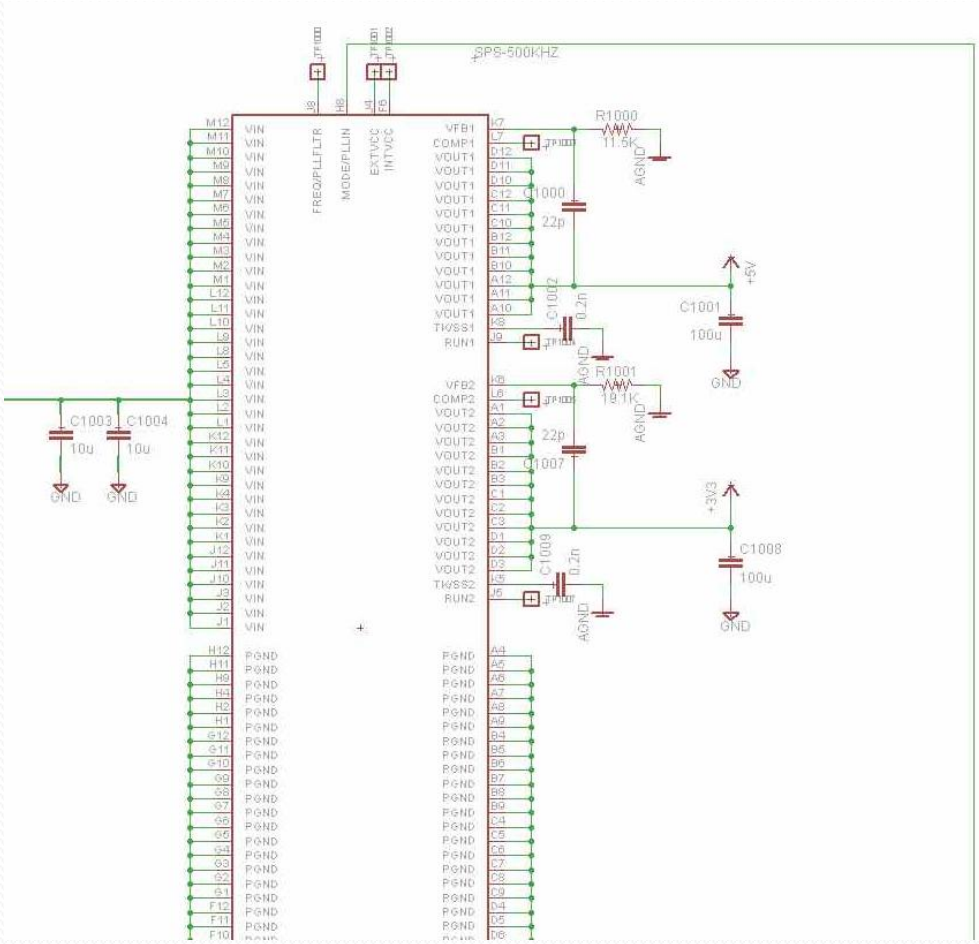
This fuse protects the SPS from currents greater than 2000 mA. Its direct purpose however is to protect the power bus from a short circuit fault on the SPS side. Since the specified maximum SPS current is 2000 mA we chose a fuse rated at 2000 mA. The opening time for the fuse according to its datasheet is .05 s at a current of 8 A, or 5 s at 5 A. Currents of 2 A or below are 4 hours minimum, therefore this fuse will only protect the SPS or power bus from gross currents due to some fault on either side (power bus or SPS) and not to keep the SPS output current within spec, that is U1001's job



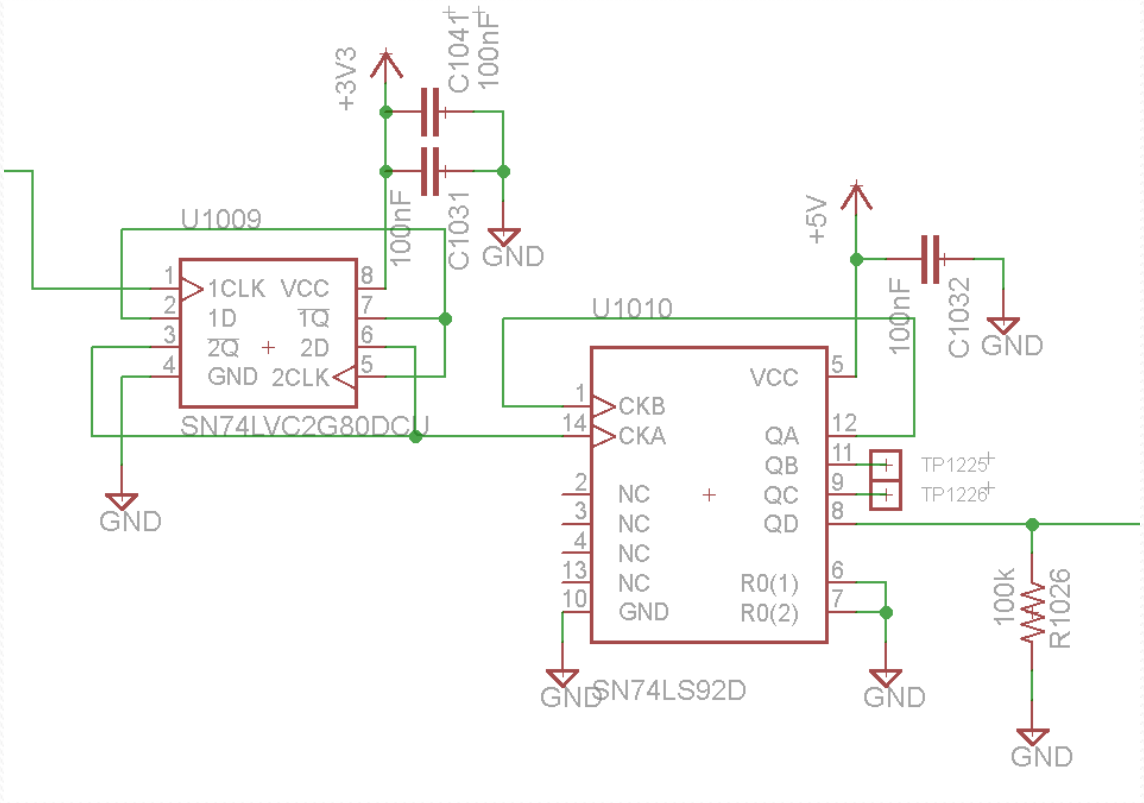
SPS

- LTM4619 micro module
  - Vin = 4.5V ~ 26.4V
  - Iout = 4A
- Output
  - 5V, 500mA
  - 3.3V, 2.2A
- 500kHz synchronized switching
- 80% efficiency
- 1.5% DC Voltage error

LTM4619


SPS-500KHZ
R1000
11.5K
AGND
C1000
22p
C1002
0.2n
C1001
100u
+5V
GND
R1001
19.1K
C1007
22p
C1009
0.2n
C1008
100u
+3V3
C1003
10u
C1004
10u
VIN
PGND
VOUT1
VOUT2
VFB1
VFB2
COMP1
COMP2
RUN1
RUN2
TK/SS1
TK/SS2
FREQ/PLLFLTR
MODE/PLLIN
EXTVCC
INTVCC

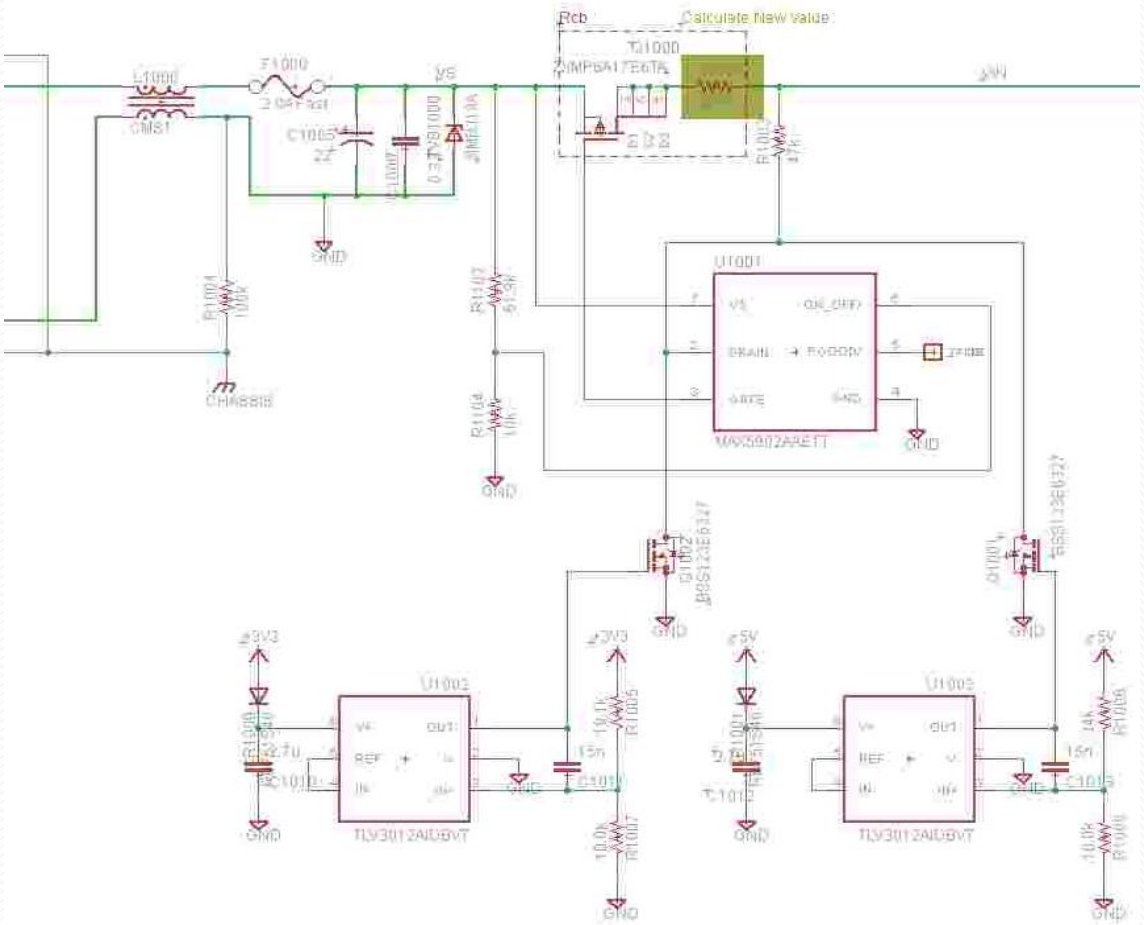
Frequency Divider (24MHz to 500KHz)



Protection

- Over Current Protection at 1.6A
- Under Voltage Lockout = 9V
- Overvoltage Lockout at SPS-5V Bus = 5.45V
- Overvoltage Lockout at SPS-3.3V Bus = 3.6V
- Die temperature = +125°C

Protection Circuitry



TQM5200:

- Freescale PowerPC Processor MPC5200 up to 400MHz with MPC603e Processor Core
- 33MHz Oscillator for the CPU-Clock
- Silicon Motion Graphic Controller SM501 with 8MB internal graphic memory
- 24MHz Oscillator for the Graphic Controller
- SDRAM: 16MB up to 128MB1 / 256MB2; 32Bit data length
- Flash: 4MB up to 32MB Flash3 Data length : 32Bit
- SRAM: 512kByte or 1Mbyte, data length: 16-Bit. Possibility of buffering the battery by the Basis-Hardware
- Serial EEPROM: okBit up to 64kBit, I2C-Bus
- CPLD for Reset-Configuration and activation of SRAM and Graphic-Controller
- Driver for two serial interfaces (RxD, TxD)
- 32-Bit Bus driver and 24-Bit Address Register for module components at the Local-Plus-Bus
- COP/JTAG Interface
- Single Power Supply 3.3V
- Switch-Mode DC/DC Converter on the Module (3.3V on 1.5V)
- Linear DC/DC Converter on the Module (3.3V on1.8V)
- 3.3V Supervisor/Power-Fail-Logic with SDRAM Battery Backup
- 240 Pin + 80Pin (320Pin) Board-to-Board connector system

TQM5200 (Cont…):

TQM5200 Connector

Two 40 pin connector :
- Part Number: 179030-1
- Connector Style = Plug
- 40 Positions
- PCB Mount Angle = Vertical
- Board-to-Board Stack Height = 7.00 mm, 11.00 mm, 15.00 mm, 19.00 mm

Two 120 pin connector :
- Part Number: 179030-5
- Connector Style = Plug
- 120 Positions
- PCB Mount Angle = Vertical
- Board-to-Board Stack Height = 7.00 mm, 11.00 mm, 15.00 mm, 19.00 mm

System Component:

CPU Main
MPC603e series G2_LE core
Superscalar architecture
760Mips at 400MHz (-40 to +85°C)
450Mips at 264MHz (-40 to +105°C)
16k Instruction cache, 16k Data cache
Double precision FPU
Instruction and Data MMU
Standard & Critical interrupt capability

SDRAM / DDR Memory Interface
up to 133MHz operation
SDRAM and DDR SDRAM support
256-MByte addressing range per CS, Two CS available
32-bit data bus
Built-in initialization and refresh

External Bus Interface
Supports interfacing to ROM/Flash/SRAM memories or other memory mapped devices
8 programmable Chip Selects
Non multiplexed data access using 8/16/32 bit data bus with up to 26 bit address
Short or Long Burst capable
Multiplexed data access using 8/16/32 bit data bus with up to 25 bit address

Peripheral Component Interconnect (PCI) Controller
Version 2.2 PCI compatibility
PCI initiator and target operation
32-bit PCI Address/Data bus
33 and 66 MHz operation
PCI arbitration function

TQM5200 (Cont…):

ATA Controller

Version 4 ATA compatible external interface

6 Programmable Serial Controllers (PSC)

UART or RS232 interface

CODEC interface for Soft Modem, Master/Slave CODEC Mode, I2S and AC97

Full duplex SPI mode

IrDA mode from 2400 bps to 4 Mbps

Fast Ethernet Controller (FEC)

Supports 100Mbps IEEE 802.3 MII, 10Mbps IEEE 802.3 MII, 10Mbps 7-wire interface

Universal Serial Bus Controller (USB)

Version 1.1 Host only

Support for two independent USB slave ports

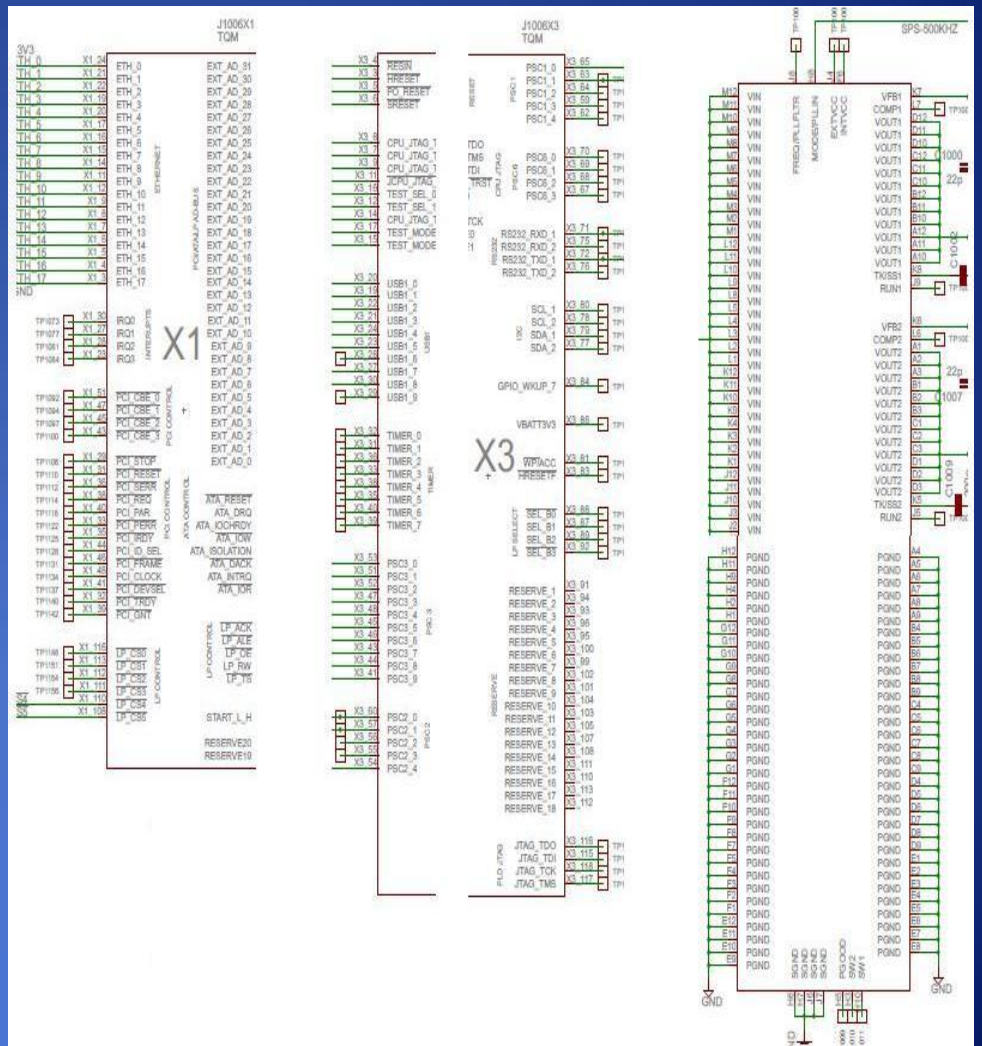
Two Inter-Integrated Circuit Interfaces (I2C)

Serial Peripheral Interface (SPI)

Dual CAN 2.0 A/B Controller (MSCAN)

Motorola Scalable Controller Area Network (MSCAN) architecture

Implementation of version 2.0A/B CAN protocol Standard and extended data frames



Testing:

Test Title	Condition	Expected Results
Under voltage on the Input	Assert VS node smaller than 9V	Q1000 MOSFET will be turned off in 4us.
Over Current on the Input	I > 1.62A (Assert current on VS node)	Q1000 will be turned off in 4us.
>>Over current disappear	I < 1.62A	over current event disappear after Q1000 turns off within 150 ms, then the normal start sequence is reinitiated.
Over voltage on SPS-5V output	Assert more than 5.46V on 5V bus	1.)Q1001 will be turned on. 2.)Q1000 will be turned off.
Over voltage on SPS-3V3 output	Assert more than 3.6V on 3V bus	1.)Q1002 will be turned on. 2.)Q1000 will be turned off.

Conclusion:

The initial requirements included a compact flash card connector for data storage. But after some early testing by the PSAS team, they found out the SBC had some trouble communicating with the CF at UDMA (which was the method of choice for data transfer.) So this required a change of plan and design.

The presence of buffer between different modules on the STK and the main connectors made it difficult to run some pin testing on the board.

The board was schedule to be a part of the LV2 launch sometimes in July but because of delay during the design process, that target was not reached.

Final Size of the Board – 4.6” x 3.84”

References

http://www.memorydepot.com/ssd/listcat.asp?catid=EDC400044A

http://www.mini-box.com/4GB-40-pin-Embedded-Disk-Card-4000