

Project Specification

**Project Name: ATLAS Calorimeter First Level Trigger-
Timing Control Module**

C N P Gee

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Distribution for all updates:

Project Manager:	V. J. O. Perera
Customer:	C. N. P. Gee
Group Leader responsible for Project:	R. N. J. Halsall
Project Design Engineers	A. O. Davis
Project Managers of related projects:	B. M. Barnett
	P. Hanke
	U. Schäfer
	S. Silverstein
	R. Staley
Account Manager:	S.P.H. Quinton
Level-1 Calorimeter Trigger Project manager	E. Eisenhandler

ATLAS Level-1 Calorimeter Trigger

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1 Scope

The ATLAS Level-1 Calorimeter Trigger (L1Calo) [2.1] consists of three subsystems:

- the Pre-processor, which converts analogue pulses from the ATLAS calorimeters to calibrated digital transverse energy (E_T) values, and prepares and transmits these data to the following stages of the trigger;
- the Cluster Processor (CP) subsystem, which identifies and counts isolated e/γ and τ candidates;
- the Jet/Energy Processor (JEP) subsystem, which identifies and counts energetic jets and computes the missing, total, and jet transverse energies.

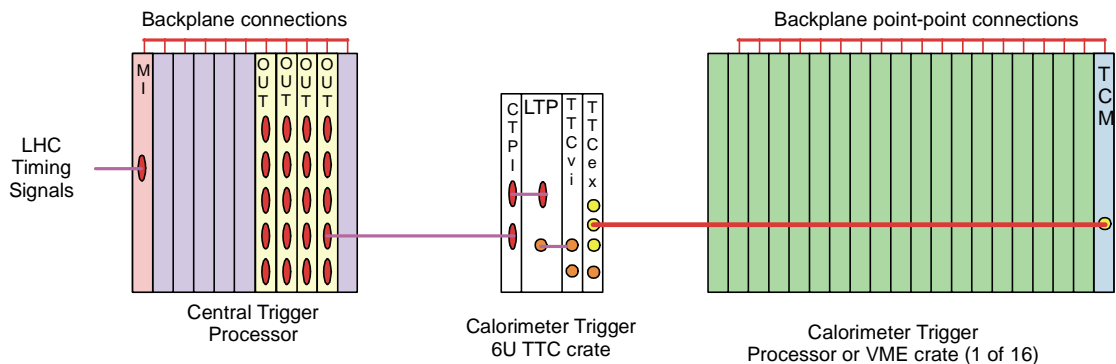
The subsystems operate together as a pipeline processor running at the LHC bunch-crossing frequency of 40.08 MHz. A precision clock of this frequency is provided from the LHC machine, and is distributed to detector subsystems within ATLAS over the Timing, Trigger and Control (TTC) system [2.2]. Within L1Calo, the clock is distributed to every module. The Timing Control Module (TCM) specified in this document provides the final stage of the clock distribution. A TCM is needed in each crate to do this.

For reasons of economy and convenience, the TCM is used for two ancillary functions unrelated to the primary clock distribution. The first is to provide an interface to the ATLAS Detector Control System (DCS), which monitors and controls operating conditions of the experiment. Each TCM provides a DCS interface, forwarding temperature and voltage information from all modules in a crate. The architecture for these functions is further described in section 1.2.

The second ancillary function is to provide a diagnostic VME bus display, which is particularly necessary for the custom backplane in CP and JEP crates.

1.1 TCM Timing Control

The chain of timing connections used in ATLAS is shown in Figure 1.



LHC-TCMTiming 050805.cvs

Figure 1: Timing connections from LHC machine to Trigger Crates.

Precision timing information is sent from the LHC machine to the “Machine Interface” module of the Central Trigger Processor (CTP). After passing over the CTP backplane, timing signals are distributed from Output modules over twisted-pair electrical ribbon cable to all ATLAS sub-systems. The timing information includes the 40.08 MHz clock, the LHC Orbit signal, the Level-1 Accept (L1A) signal, the Trigger Type, and the Event

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Counter Reset signal. In test rigs, the clock is generated within the TTCex, and other signals are generated by NIM logic or under software control.

In either case, the signals are received at the calorimeter trigger in a 6U VME crate by the CTP Interface module. After passing through the Local Trigger Processor (LTP) module, the information is encoded by the TTCvi module into a single serial signal, and then distributed optically from the TTCex module.

The final stage of distribution is provided by the TCM, which receives and converts the TTC optical signal to differential electrical format, to be sent to individual modules over the CP/JEP crate backplanes or via backplane interconnects in VME64x crates. On receipt in the destination modules, the TTC electrical signal is passed to a TTCdec decoder card, where a TTCrx chip recovers the clock and other signals and presents them for use on the module.

1.2 CANbus Controls

The control and monitoring system is shown in Figure 2. In the Calorimeter Trigger, it is responsible for temperature and voltage monitoring for all of the modules. A separate CANbus monitors crate supplies and fan speeds, and a separate subsystem (the responsibility of central DCS) controls and monitors rack environmental conditions.

Every module in the Calorimeter Trigger includes a CANbus node (shown as “N” in the figure) connected to board sensors measuring temperatures and voltages. These nodes are connected via the backplane to a CANbus bridge “B” in the TCM. A second port of the bridge is connected via an external CANbus network to a Local Control Workstation (LCS) computer, where information is gathered from all L1Calo crates. The LCS acts as the interface to the DCS system for the whole of the ATLAS experiment, sending error messages to the central control room when problems occur.

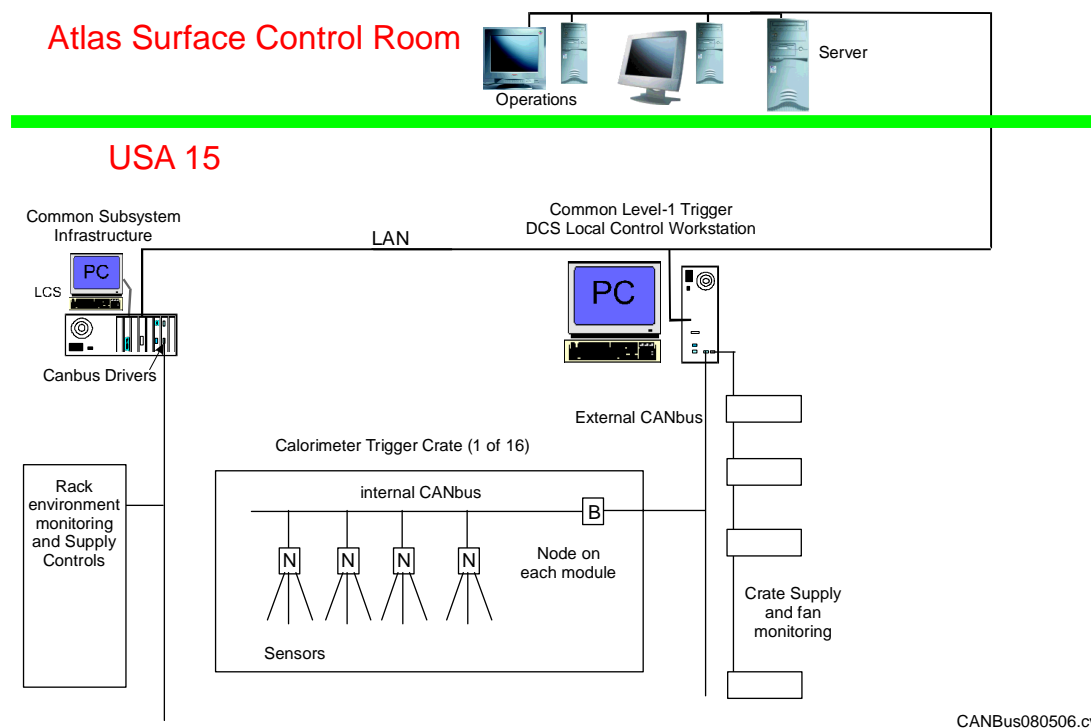


Figure 2: ATLAS DCS architecture

2 Related projects and documents

- [2.1] ATLAS TDR at <http://ATLASInfo.cern.ch/ATLAS/GROUPS/DAQTRIG/TDR/tdr.html>
- [2.2] TTC documents at <http://www.cern.ch/TTC/intro.html>
- [2.3] Reduced VME specification via <http://hepwww.rl.ac.uk//ATLAS-L1/TIN/TIN.htm>
- [2.4] Common CP and JEP Crate backplane specification via <http://hepwww.rl.ac.uk//ATLAS-L1/Modules/Components.html>
- [2.5] Use of TTC system and Busy network, at <http://hepwww.ph.qmul.ac.uk/11calo/doc/pdf/TTCBusy.pdf>
- [2.6] MB90F590 series microcontroller datasheet and reference manuals, at <http://www.fme.gsdc.de/pdf/ds90590-ds07-13704-5e.pdf> and <http://www.fme.gsdc.de/pdf/hm90590-cm44-10105-4e.pdf>
- [2.7] ATLAS DCS system- <http://ATLASInfo.cern.ch/ATLAS/GROUPS/DAQTRIG/DCS/dcshome.html>
- [2.8] Hewlett Packard HFBR 2316T Data Sheet, via <http://www.home.agilent.com>
- [2.9] VME Mount module, via <http://hepwww.rl.ac.uk//Atlas-L1/Modules/Modules.html>
- [2.10] TCM Test plan, via <http://hepwww.rl.ac.uk//Atlas-L1/Modules/Modules.html>

3 Technical Aspects

The module is 9U to meet the IEEE1101.10 standard crate specification.

Two versions of the module are required. They are functionally almost identical, except with regard to the mechanical and electrical interfaces to the crate backplanes and the different addressing and data modes available with the full VME backplane.

The first version, TCM-CP/JEP, fits processor crates with the custom backplane in which the CP and JEP subsystems are housed. The backplane supports a subset of the VME standard, referred to as "VME--" and defined in [2.3].

The second version of the module, TCM-VME, fits the 9U VME64xP and VME64x crates housing the Preprocessor and ROD subsystems respectively. This version supports the full VME64x bus protocol.

Six prototype modules have been built to demonstrate functioning, and have been used for combined system tests. Initially two production modules of each type should be manufactured, followed by further modules to produce the quantities in Table 1.

TCM-CP/JEP:	CP and JEP Crates	6
	Test Rigs	3
	Spares	4
	TOTAL	13
TCM-VME	PP Crates	8
	ROD Crates	2
	Test Rigs	4
	Spares	4
	TOTAL	18

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Table 1: Production module quantities for TCM

3.1 Functional Requirements

These requirements apply to both versions of the module, except where stated.

- a) Receive an optical signal from a local TTC system, convert to electrical signalling, and distribute to crate backplane connector as differential LVPECL standard signals.
- b) Provide VME-readable and front-panel indicator of loss of TTC optical signals.
- c) Provide a CANbus processing node with interfaces to the external CANBus via a front-panel connector and to the internal crate CANbus via the backplane.
- d) Interface to the VME64x and VME64xP, or VME--, backplanes.
- e) Provide LED and Numeric displays of VME64x and VME64xP, or VME--, transactions
- f) Provide a VME read/write memory for CANbus data access and crate testing purposes.
- g) Generate VME64 or VME-- bus reset on receipt of appropriate CANbus command.
- h) Provide VME-- backplane termination (TCM-CP/JEP only).
- i) Set the geographical crate number (TCM-VME only).
- j) Provide VME64x- and VME64xP-compatible distribution of CANbus, TTC and geographical address signals (TCM-VME only).

3.2 Functional Details

3.2.1 Timing Functions

The optical signals from the TTC system are Time Division Multiplexed using Bi Phase Mark encoding onto multimode 50/125 μm fibre at 1300 nm. The fibre is fitted with ST connectors.

Optical TTC signals are converted to electrical signalling and fanned out over point-to-point links in the CP/JEP or VME backplanes. LVPECL differential levels are used with series termination. A front-panel Lemo-00 connector provides a copy of the encoded TTC signal for monitoring purposes.

The Link Status output from the optical receiver is monitored through the VME interface and provides a Link Status LED on the front panel. Transient signal loss is latched.

Electrical monitoring points are provided for the various phases of the signal chain.

Internal signal tracking where appropriate is specified as 100 ohms, and tracking to backplane output connectors is specified as 100 ohms differential to match the backplane connections.

Tracking to the front panel Lemo connector is specified as 50 ohms to match the cable.

The differential front-panel PECL outputs provided in the prototype module are not required.

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3.2.2 DCS and CANbus functions

This section comprises a Fujitsu MB90F594 micro controller [2.6] with interfaces to the local crate CANbus and to the external CANbus. A diagnostic connection to the local and external CANbus is provided on the front panel.

A common slow controls architecture is used throughout the calorimeter trigger. Functions are implemented in firmware, and responsibilities are divided as follows:

- Microcontrollers on individual modules measure voltages and temperatures at regular intervals, check the values against limits, and send alarms to the TCM when limits are exceeded (no voltage measurements are made on the TCM itself).
- The TCM microcontroller reads measured values from every node at roughly one-second intervals, and creates a table of all values in one crate. The TCM also forwards alarms directly to DCS over the external CANbus. The TCM can load the individual node limits at system startup – details are to be decided.
- DCS reads values from all TCMs when required, via Ethernet to the LCS, then via the external CANbus to TCMs. DCS records the values in a database, and also processes any alarms. DCS also monitors readout from crate power supplies and environment sensors in racks.

A watchdog timer is provided to check for CANbus activity in the crate.

The TCM microcontroller can be programmed via a front panel connector and reset both from the front panel and via VME.

3.2.3 VME Functions

A VME interface is provided with the following functions:

- a) Reset the CANbus controller from VME;
- b) Assert VME SYSRESET from the CANbus controller;
- c) Read over VME the version number of the CANbus controller code; and
- d) Allow VME read/write information exchange with the CANbus controller via a dual-port memory. This allows the local single-board computer to obtain temperature and voltage values without connection to DCS. The dual-port memory also serves as diagnostic VME read/write memory for crate testing.

3.2.4 Crate Number setting

VME64x and VME64xP provide a set of five Geographical Addressing pins, GA0*-GA4*, which a module may use to determine its slot number within a crate. L1Calo defines four further custom pins GA5*-GA8* in the J0 connector of ROD and Preprocessor crates to provide crate number addressing. The crate number is distributed over a supplementary backplane to the J0 connector at each module position. Solder pads are provided on this backplane to set the crate number by selectively grounding these signals, using the connections shown in Table 2. The solder pads should be laid out so that surface-mount switches may be attached for use in a test lab (where the crate number may be changed many times). These signals are active low, to meet the VME64 specification.

In CP/JEP crates, three pins GA4-GA6 are identified by the custom backplane specification, and the crate number is determined by setting a switch on the backplane itself, using active-high signalling (the opposite of the VME standard).

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The crate number is readable in a register and via front-panel LEDs. The values displayed have been decoded to give the crate number, so that knowledge of logic levels for the different backplane types is not needed to interpret the display.

Crate No	GA8*	GA7*	GA6*	GA5*
0 – PPM	Open	Open	Open	Open
1 – PPM	Open	Open	Open	GND
2 – PPM	Open	Open	GND	Open
3 – PPM	Open	Open	GND	GND
4 – PPM	Open	GND	Open	Open
5 – PPM	Open	GND	Open	GND
6 – PPM	Open	GND	GND	Open
7 – PPM	Open	GND	GND	GND
14 – ROD	GND	GND	GND	Open
15 - ROD	GND	GND	GND	GND

Table 2: VME64x and VME64xP crate geographical address pin assignments.

4 PCB Layout

The approximate module layout is shown in [Figure 3](#), where the differences between the two versions are illustrated. The TCP-CP/JEP version obtains power from the bottom of the board, VME signals from the VME-- bus at the top, and sends TTC and CANbus signals through the connector at the bottom.

In the TCM-VME version, power, VME64 plus TTC and CANbus signals, are connected in the upper part of the board. For this version of the module, the J3 area is not connected – incompatible connectors are used in the Preprocessor and ROD crates, and the module must not interfere with the connector in either crate.

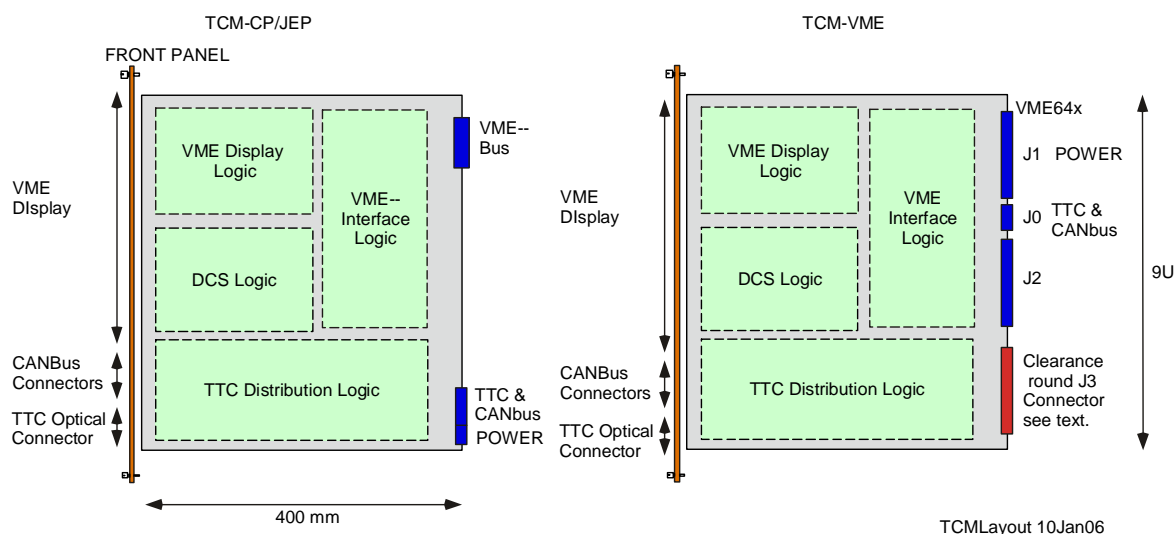


Figure 3: TCM layout.

5 Implementation

5.1 TTC Interface

Optical TTC signals are received into a Hewlett Packard HFBR 2119T optical to electrical converter, a compact 16 pin package with integrated ST connector. The outputs of the HFBR2119T are PECL compatible. The PECL output is converted to LVPECL and then fanned out to 20 LVPECL differential point-to-point links via the CP/JEP backplane or 19 via the VME backplane. As some of the crate slots will be unused, the TTC signals must be series terminated at source. Extended swing fan-out cable drivers of type SY10EP89V are used to provide the drive capability through the series termination. A copy of this signal is also provided to a standard Lemo-00 connector on the front panel for monitoring purposes. This will be ~ 500 mV ac-coupled to 50Ω load. Note that this is the encoded TTC signal, not the 40.08 MHz clock.

The TTC optical light level is monitored in the TCM, and if it falls below the minimum required, the optical signal failure condition is latched. This condition is reported in the VME status register and by a front-panel LED, and is cleared by a control register bit.

5.2 VME Interface

The TCM-CP/JEP uses the VME-- bus. All cycles are interpreted as A24, D16. In VME64x and VME64xP bus systems, the module should respond only to A24 and A32 address cycles. The module does not support VME64 configuration space. VME interfacing is implemented in a CPLD.

5.2.1 CANbus/VME Test Memory Structure

The module uses four dual-port memories, organised as shown in [Figure 4](#), to provide memory for VME testing and CANbus-VME information exchange. VME address lines A1-A12 are used without multiplexing, so the available memory is 2042 locations deep (the devices are 2048 locations deep, but the low 6 addresses are taken for the module registers).

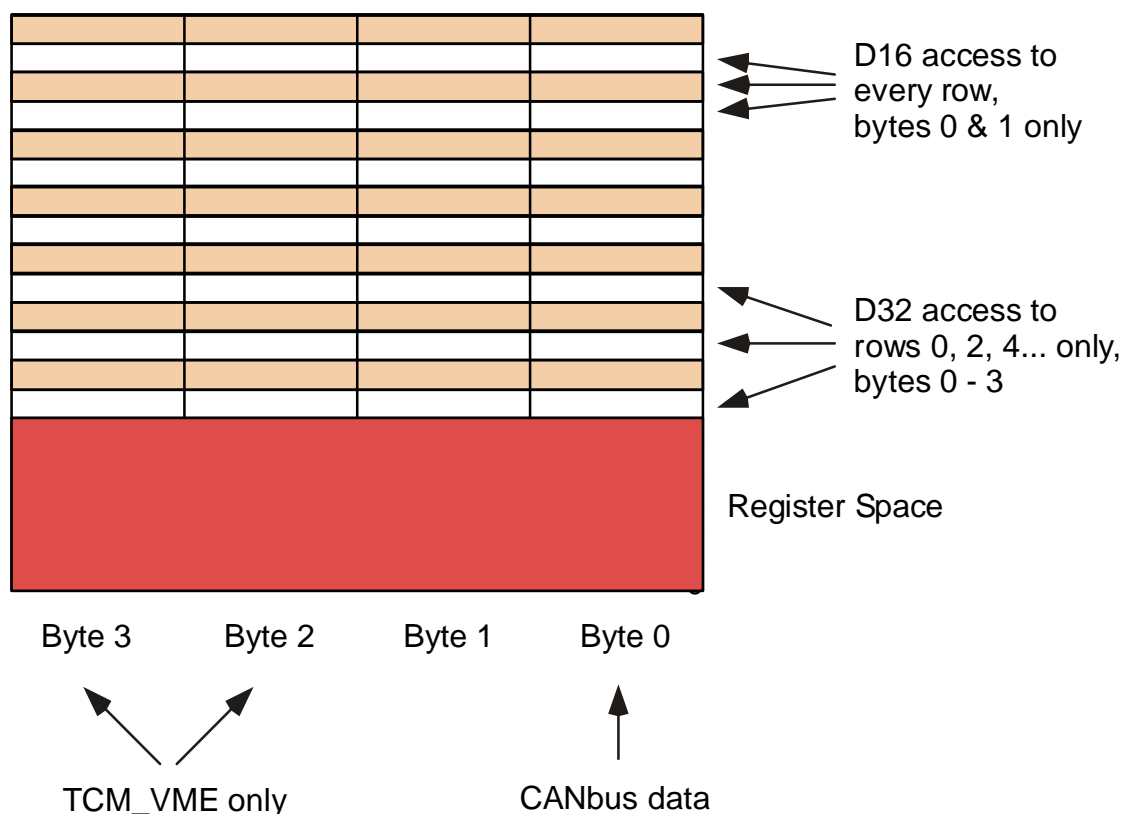
The CANbus controller updates the Byte 0 column to contain the latest values read from modules in the crate, starting at row seven (the first free row). CANbus does not use columns containing bytes 1-3.

VME access to the memory is either in D16 or D32 mode, where it appears as a block of 4084 bytes, organised as 2042 words or 1021 longwords. It is important to note that to keep the circuitry simple, the D32 memory view overlaps only partially with the other memory views.

5.2.1.1 D16 memory access

In D16 mode, VME accesses at successive word addresses read or write successive rows of columns byte 0 and byte 1 only (i.e. VME D16 never accesses bytes 2 and 3). When CANbus is operating normally, the low eight bits from each VME read operation contain the CANbus data.

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CAN_Test_Mem12Jan06.cnv

Figure 4: CAN/Test Memory organisation.

This memory can also be used for VME D16 read/write tests. CANbus operation should be disabled for such a test, using the Disable Can Controller bit in the Control Register. The VME D16 memory is 2042 words deep.

5.2.1.2 D32 Memory access

When used in D32 mode, a VME read or write will access all four bytes of a memory row. The next consecutive VME address accesses the next even-numbered row (i.e. one row is skipped). For this reason, the D32 memory is 1021 longwords deep, ending at the same place as the D16 memory. D32 access should not be used to exchange data with the CANbus controller, as the odd-numbered memory rows are not visible (unless the module is accessed at odd-word boundaries).

5.3 CANbus Interface

The CANbus addressing scheme is determined in firmware, and different schemes are used for the local and external CANbus. Each CANbus node provides 16 buffers which may be individually addressed. In some cases, input buffers from all modules in a crate are assigned the same address, so that all will receive a command which is effectively broadcast. When this happens, nodes are programmed to respond after a delay depending on the slot number to avoid bus contention.

Individual local CANbus addresses are structured as `tttsssssbbbb` (LSB), where `t` is the module type, `s` is the crate slot number, and `b` is the buffer number. The module type, `t`, is

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set to a fixed code for the TCM module type. The details of this code can be found in the addressing scheme for the TTC and Busy network [2.5]. The TCM code is 0x05.

External CANbus addressing is set by firmware, and depends on the function being executed. The crate number is used to determine delays in responding to broadcast commands received by cable.

The external CANbus must inter-work with the LCS, and an implementation of the CANOpen protocol is being considered for this.

5.3.1 *CANbus Signal I/O*

The external CANbus signals are obtained from a front panel male DB9 connector. The CAN+ and CAN- signals pass directly to an optical isolator. The CAN GND pin is connected to a solder pad. A nearby solder pad connected directly to module ground allows a simple network to be inserted between CAN GND and module ground. These solder pads should be manufactured with a 100nF capacitor.

A separate pair of solder pads allows a network to be placed between the CANbus connector shield and module ground. These solder pad will not be bridged during manufacture. The DB9 connector type used must make the metal shroud available for connection.

To maintain the external CANbus isolation, a separate DC-DC converter should be used to supply VCC to the CANbus optical isolators.

5.3.2 *CANbus Watchdog Timer*

A watchdog timer provides a hardware confirmation that periodic checking of data values is happening within the CANbus system. The circuit monitors the Tx signal on the crate side of the CANbus controller, resetting the timer to zero each time a transmission is detected. If the timer expires (after 10 ± 1 seconds), the CANbus active bit is cleared in the status register and LED display.

5.4 Inputs and Outputs

5.4.1 Front Panel Monitoring (LEDs)

The majority of the front panel is occupied by the VME bus display, as shown in Figure 5. Where possible, colours and behaviour follow a common convention throughout the calorimeter trigger. Fast signals are stretched so that they light the LEDs for long enough to be seen. The hex display and VME Bus display are all red. For other LEDs, green indicates normal static conditions, yellow indicates transient operating conditions, and red indicates errors.

The front panel LEDs consist of four blocks:

- At the top of the panel, an 8-digit hexadecimal display shows values from VME address or data lines. In the TCM-CP/JEP, the upper two bytes of data and the uppermost single byte of addresses should display a zero. A switch below the display determines if addresses or data are shown.
- Below the switch, a dual column of 32+32 small red LEDs displays the address and data lines D0-D31 and A0-A31. Every fourth bit is marked, and every eighth labelled. LED A0 is not driven.
- Below these, a block of small red LEDs displays VME protocol, addressing and crate number bits. The signals displayed are listed in Table 3.
- The final block of LEDs relates to crate power, CANbus and TTC. The signals are listed in Table 4.

Left	Right
AM5	G3
AM4	G2
AM3	G1
AM2	G0
AM1	AS
AM0	DS1
BBSY	DS0
DTACK	WRITE
BERR	LWORD
IRQ	SYSFAIL
	SYSRESET

Table 3: VME Protocol signals displayed

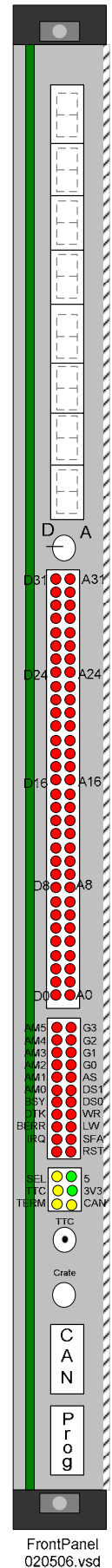


Figure 5: Front Panel

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The crate number is derived from GA4-GA6 in the TCM-CP/JEP, and by inverting GA5*-GA8* in the TCM-VME, so that in both cases a human-readable crate number is displayed in LEDS G0-G3. On power-up, the hexadecimal display should show the crate number until the first VME cycle is performed. The crate number is permanently displayed in the LED display.

The hexadecimal display is refreshed cyclically. To avoid misleading display due to data values changing while the display is being drawn, the data should be latched and held constant throughout the display cycle.

Description	Colour	Panel Label
+5 Volts	Green	5V
+3.3 Volts	Green	3V3
Module Select	Yellow	SEL
TTC Optical Signal Lost	Red	TTC
CANbus Active	Yellow	CAN

Table 4: Power, CANbus and TTC status Indicators

5.4.2 Front Panel Inputs and Outputs

The front panel provides an optical input connector of type ST which is integral to the HP HFBR-2316T Receiver. This connects to the TTC signal distribution logic.

A female LEMO-00 connector is provided containing the encoded electrical TTC signal.

A female DB9 connector is provided to program the CANbus controller, as on other L1Calo modules. The pinout for this connector is provided in [Appendix C](#).

A male DB9 connector is provided for the external CANbus cable.

5.4.3 Backplane Input and Outputs (TCM-CP/JEP)

The CP/JEP version of the TCM interfaces to the VME-- processor backplane at the top to access to the VME signals needed for monitoring, and at the bottom to obtain +5V power (3.3V is reserved for LVDS use only) and to access the TTC timing signals and internal crate CANbus signal pins. The backplane pinout is given in full in Appendix A.

All signal and clock traces to or from the backplane carrying signals at or above 40 MHz must have controlled impedance matching that of the backplane.

5.4.4 Backplane Input and Outputs (TCM-VME)

The TCM-VME is used in Preprocessor and ROD crates, which have different types of connectors in the lowest 3U position. The TCM does not use either of these and should maintain adequate clearance round both.

In the upper 6U of the backplane, the TCM-VME connects to the J1, J2 and J0 connectors of a VME64xP (Preprocessor) or VME64x (ROD) backplane. These backplanes are mechanically compatible, and have been chosen for their capability to supply different power levels. The TCM-VME should leave unconnected any pins specified differently in the two standards. In particular, a +48V supply is used on the VME64x +V1 and +V2 lines, as permitted on P1/J1 within the VME64x standard. Extra care is needed to avoid

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shorts when working with this version of the crate. The TCM should not use the 3.3V, 12V and 48V lines.

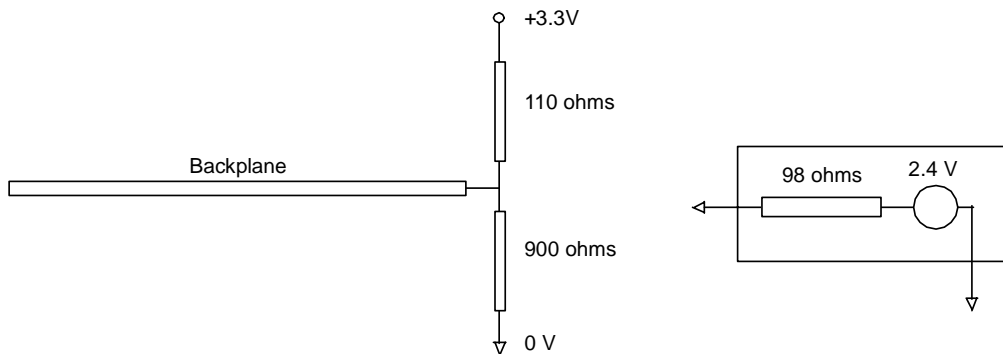
The TCM-VME does not provide VME backplane termination.

In both VME64x and VME64xP, the TTC and internal crate CANbus signals are connected to the user-defined pins on the J0 connector, whose pin-out is given in [Appendix B](#).

All signal and clock traces to or from the backplane carrying signals at or above 40 MHz must have controlled impedance matching that of the backplane.

5.4.5 Backplane Termination

VME termination for the TCM-VME is provided by the VME backplane itself. However, the TCM-CP/JEP should provide termination for the active VME-- signals. The terminations used should be identical to those used in the VMM [2.9]. With the exception of DS*, all active VME-- signals should be terminated to VME standards (i.e. equivalent to 2.94V via 196 ohms). In the case of DS*, additional drive capability has been provided from the VMM to improve signal timing characteristics. This signal should be terminated as to 2.94V via 98 ohms, as shown in [Figure 6](#) where the Thevenin equivalent is also shown.



Termination 160306

Figure 6: Termination of DS* VME-- signal.

5.4.6 External CANbus termination

The external CANbus cable is manufactured as a daisy-chain, using halogen-free cable (for example CERN stores 04.21.51.102.4). The TCM does not provide termination, so appropriate resistors should be soldered into the final cable connector.

5.4.7 Keying

The TCM will be used only in slot 21 of VME--, VME64x and VME64xP crates, and should be keyed accordingly.

5.4.8 VME64 Auxiliary Backplane

There are no suitable traces in the VME64x and VME64xP backplane to carry the crate geographical address, the TTC and the CANbus signals. An auxiliary backplane is therefore added at the rear of the crate, pushing into the rear of the J0 connectors in the VME64 backplane. This auxiliary backplane, illustrated in [Figure 7](#), distributes the three sets of signals from slot 21 rear J0 connector to the 19 slots numbered 2 to 20 (although slots 1 and 2 are reserved for 6U modules). The geographical addresses and CANbus signals are bussed, while the TTC signals are point-to-point.

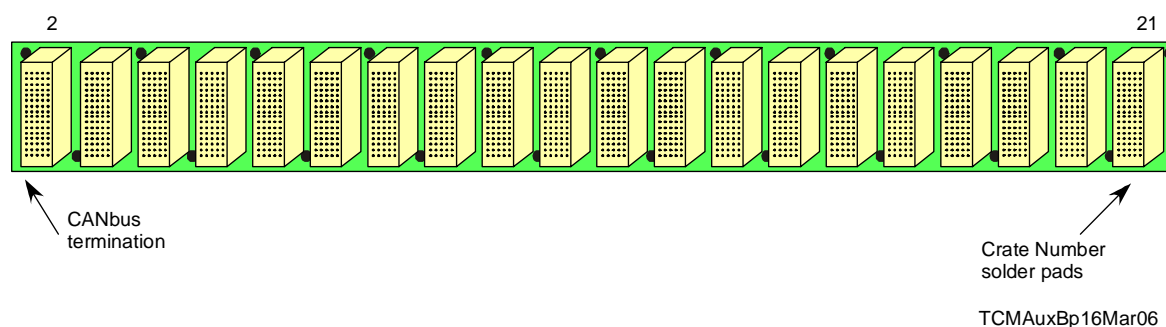


Figure 7: Auxiliary backplane for VME64x and VME64xP crates.

The backplane should provide trace of 120 ohm differential impedance for the CANbus and should be terminated with 120 ohms close to slot 2.. The TTC signal traces will be 100 ohm differential impedance,.

The J0 connector has 133 pins, so an auxiliary backplane with 20 slots would require 2660 contacts, giving a very high insertion force and making it nearly impossible to remove. A flexible backplane would tend to tear at the edges of connectors. The preferred option is therefore a rigid backplane using connectors with fewer pins at slots 3 to 10 and 12 to 20 to reduce insertion force, leaving fully populated connectors for slots 2, 11, (without rows f and Z) and 21 (with rows f and Z) to guide the backplane during insertion. It is straightforward to remove unwanted contacts from the (auxiliary backplane) connectors. The auxiliary backplane thickness must be sufficient to resist bending when being inserted and removed.

Backplane dimensions should be chosen to avoid clashing with the ROD S-Link RTM, the PPM G-Link RTM, and the power supply connectors in the J0 area. Requirements for solder pads to set the crate number are described in section [3.2.4](#).

The backplane connectivity is included in [Appendix B](#). Compared to the ROD, the PPM requires extra pins which are not internally connected in the backplane. A full hole matrix is drilled at each slot, although only the TTC, CANbus, GEOADD and Ground pins should be internally connected. Small holes (e.g. M4 clearance) should be provided between slots to allow jacking screws to be added at intervals to assist in backplane removal of the PPM version. These should be alternately near the top and near the bottom of the backplane, placed so that the screws bear on the PCB between VME64X J0 sockets.

Auxiliary backplanes should normally not need to be changed, so may be plugged permanently onto crates, including test and spare crates. The number of backplanes needed, shown in [Table 5](#), depends on the number of crates bought, not the number of TCMs.

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Item	PPM crates & connectors	ROD crates & connectors
Crates in USA15	8	2
Spare Crates	3	1
Test Rigs	2	3
Spares	2	2
TOTAL	15	8

Table 5: Auxiliary backplane manufacturing quantities.

5.5 Grounding

The only cable normally connected to the TCM is that carrying the CANbus signals. Grounding is described in section [5.4.2](#).

5.6 Power Requirements

All power required by the module is derived from the +5V supply. The 3.3V supply on TCM-CP/JEP backplanes is reserved for LVDS signalling devices, so an internal regulator is used to generate the 3.3v supply. The total current drawn at +5V may be up to 5A.

5.7 Instrument Access points

5.7.1 Test and Set-up Points

Oscilloscope test points are provided for the different stages of the TTC signal chain, and to monitor the internal and external CANbus connections. A test point is also required in the SYSRESET line from the CANbus controller.

JTAG connections are provided between JTAG-compliant devices so that as much as possible of the board layout can be tested automatically.

5.7.2 Ground Points

Ground points are provided for scope probe grounding in exposed areas of the motherboard.

5.8 Programming Model

5.8.1 Guidelines

These are to aid the software control of the module.

1. The computer can read all registers, hence there are no 'write only' registers. The register bits generally have the same meaning for reads as for writes.
 - 1.1 All Status Registers shall be read-only registers.
 - 1.2 All Control Registers shall be Read/Write registers.
 - 1.3 Reading back a register generally returns the last value written.
 - 1.4 Attempts to write to read-only registers or undefined portions of registers result in the non-modifiable fields being left unchanged.

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2. It is illegal for the computer to read or write a value that the TCM module itself is able to modify at the same time.
3. If the computer reads a register (e.g. a counter) which the TCM module is modifying, a well-defined value is returned, for example by synchronising the data capture to the 40.08 MHz clock.
4. When the address space occupied by the TCM module is accessed, it always responds with a handshake to avoid a bus error.
5. The power-up condition of all registers is all zeros, unless otherwise stated.

5.8.2 Notation

The names of the registers and bit fields within them are written in *italic*. The names of the signal lines are *underlined italic*. Bit-fields are labelled Input to Card and Output from Card rather than Write and Read to make it clear whether it is the card or the computer which is doing the writing.

In this document, a byte is always an 8-bit field, a word is always 16 bits and a long-word is always 32 bits.

Setting a bit-field means writing a 1 to it, clearing it means writing a 0.

RO means that the computer can only read the value of this register; writing has no effect either to the value or the state of the module.

RW means that the computer can affect the state of the module by writing to this register.

5.8.3 VME Access Modes

The TCM module supports A24 and A32 addressing, with D16 and D32 data width, using the addressing modes listed in [Table 6](#). The module responds to A24 VME addresses in the range 0x68'0000-0x6F'FFFE and to A32 addresses in the range 0x5468'0000-0x546F'FFFE. The VME-- bus does not carry AM codes, and the TCM-CP/JEP should respond assuming a standard A24, D16 cycle has been issued.

AM code	
39	Standard (A24) non-privileged data access
3D	Standard (A24) supervisory data access
09	A32 non-privileged data access
0D	A32 supervisory data access

Table 6: Supported VME addressing modes

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5.8.4 VME Register Map

The memory map and detailed assignment of bits may change during the design phase to accommodate requirements not foreseen at the time of writing this document.

The following registers are used in all types of TCM

Byte Address (hex)	Register type	Register Name	Size in bytes	Description
00000	RO	ModuleIdA	2	Module ID Register A
00002	RO	ModuleIdB	2	Module ID Register B
00004	RW	ControlReg	2	Control Register
00006	RO	StatusReg	2	Status Register
00008	RW	TestReg	2	Test Register
0000A	RW	TestReg2	2	Test Register 2
00010	RW	CAN/ Test Memory	4084	CAN/Test Memory

5.8.4.1 Module ID Register A

All bit fields are outputs from card

Bit	Descriptive Name	Signal name
0-15	<i>ModuleID</i>	<u><i>RALNo</i></u>

Module ID Number.

A unique 8-bit number for each module type, set to 3303 for the TCM VME64x and 3304 for TCM CP/JE. These numbers match the RAL PCB design numbers.

5.8.4.2 Module ID Register B

All bit fields are outputs from card

Bit	Descriptive Name	Signal name
0-7	Module Serial number	SerNo
8-11	Hardware Revision Number	RevNo
12-15	Module Type	

Module Serial Number.

A unique 8-bit number for each module, starting at 1 and set by solder jumpers.

Revision Number.

Four-bit revision number starting at 1 and set by solder jumpers.

Module Type

A four-bit field set to 0 on the TCM-CP/JEP and to 1 on the TCM-VME..

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5.8.4.3 Control Register

All bit fields are inputs to card.

Bit	Descriptive Name	Signal name
0 (LSB)	<i>Reset CAN Controller</i>	<u>CAN_RESET</u>
1	<i>Disable CAN Controller</i>	
2	<i>Reset TTC optical indicator</i>	
3-15	<i>null</i>	

Reset CAN Controller

5.8.4.3.1 Bit 0

Writing a 1 to this bit resets the CANbus Microcontroller module to the power-on state. Writing a zero has no effect other than to clear the stored value.

Disable CAN Controller

5.8.4.3.2 Bit 1

Writing a 1 to this bit disables the CANbus Microcontroller. Writing a zero enables the controller.

Reset TTC Optical Indicator

5.8.4.3.3 Bit 2

Writing a 1 to this bit clears the TTC optical link failure bit in the status register and on the front panel.. Writing a zero has no effect.

5.8.4.4 Status Register

All bit fields are outputs from card.

Bit	Descriptive Name	Signal name
0 (LSB)	TTC Optical Link Failed	
1	CANbus Active	
2-5	Crate Number	
6-15	<i>Null</i>	

TTC Optical Link Active

5.8.4.4.1 Bit 0

When this bit is set, the module has lost the optical TTC signal (now or at some time in the past).

CANbus Active

5.8.4.4.2 Bit 1

When this bit is set, CANbus activity has taken place in the crate within the last 10 seconds.

Crate Number

5.8.4.4.3 Bit 2-5

These bits read the crate number obtained from the geographical address pins, with bit 1 reading the lowest-valued pin. The value displayed is the human-readable version, independent of the backplane signalling levels.

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5.8.4.5 Test Register

This register provides a general purpose read/write register for test purposes. The values written have no active effect in the module.

5.8.4.6 Test Register 2

This register provides a general purpose read/write register for test purposes. The values written have no active effect in the module. Together with the preceding register, it provides a 32-bit read/write test register.

5.8.4.7 CAN/Test Memory

This is a block of dual-port memory for CANbus and VME test use. The organisation and use is described in section [5.2.1](#).

5.9 Connector Definitions.

These are defined in the common backplane specification, from which [Appendix A](#) is copied.

5.10 Manufacturing

An outside manufacturer will carry out PCB manufacture and assembly.

5.11 Testing

5.11.1 Test Strategy

Testing is done in stages:

1. Test the TCM internal signal transfer using LabView environment
2. System tests with Data Acquisition software in the lab environment

A test plan [\[2.10\]](#) was provided at the FDR/PRR

5.11.2 Test equipment

- (1) Powered 9U VME64x (or VME64xP) crate and powered CP/JEP processor crate with custom backplane.
- (2) Computer with A24/A32,D16/D32 VME interface
- (3) Logic analyser
- (4) Oscilloscope
- (5) TTC system (TTCvi, TTCvx, TTCrx)
- (6) VME Extender

5.11.3 Software

A test engineer from the System Support Group will develop the LabView test software.

The test software for other tests is required from the trigger group.

5.12 Installation

The TCM module is designed for slot 21 only of a 9U crate with VME--, VME64x or VME64xP backplane. The module is provided with a front panel housing sockets and monitoring LEDs. The module must be single-width to meet space constraints.

5.13 Maintenance and further orders

Production modules have an expected life span of up to 20 years.

6 Project Management

6.1 Personnel

		RAL Ext.	RAL Location
Customer:	C. N. P. Gee	6244	R1, 1.39
Project Manager:	V. Perera	5692	R68, 2.31
Project Engineer	A.O. Davis	6700	R 25, G.132,

6.2 Deliverables

Initially four pre-production modules, two of each type, and following acceptance the remainder of the production modules listed in [Table 1](#), with the firmware needed to operate the modules in CP/JEP and VME64x and VME64xP crates.

6.3 Project plan (Milestones)

1.PDR	July 1999
2.Joint FDR & PRR	November 2005

6.4 Design Reviews

The progress of the project is reported on a monthly basis in the ATLAS Calorimeter First-level Trigger project monitor form.

6.5 Training

Training is carried out as required on the job.

6.6 CAE

Cadence for schematic capture, VHDL and FPGA design tools, and LabView for test software.

6.7 Costs and finance (Cost centre: FK42400)

6.7.1 Cost Estimate

£13.6k for 13 TCM-CP/JEP modules, plus £18k for 18 TCM-VME64 modules.

6.8 Intellectual Property Rights (IPR) and Confidentiality

All background and foreground Intellectual Property Rights in this project remain with CCLRC. The trigger group has unrestricted rights to items listed under deliverables (6.2). If other data is required, then an appropriate protective agreement should be in place before releasing such data.

6.9 Safety

General laboratory safety codes apply.

6.10 Environmental impact

6.10.1 Disposal

RAL will dispose of the modules at end of their life.

6.10.2 EMC

The electronics shall comply with specifications intended to ensure operation without malfunction or unacceptable degradation of performance due to electromagnetic interference (EMI) within their intended operational environment.

7 Glossary

CP	Cluster Processor sub-system of the Calorimeter Trigger
Custom backplane	High-speed custom backplane within CP and JEP crates
CPM	Cluster Processor Module
CTP	Central Trigger processor
DCS	Detector Control System
L1A	Level-1 Accept signal distributed via the TTC system.
LCS	Local Control Station (part of DCS)
LTP	Local Trigger processor
JEM	Jet/Energy Module
JEP	Jet/Energy Processor sub-system of the Calorimeter Trigger
ROD	Readout Driver module
TCM	Timing and Control Module (specified in this document)
TTC	Timing, Trigger and Control

8 Revision History

8.1 Changes in Draft 0.7

First full version, from draft (2000) by Bob Hatley.

8.2 Changes in draft 0.7.5

Text Corrections and clarification
Added A32D32 access and addresses for A32.

8.3 Changes in draft 0.7.6

Minor text clarifications.

8.4 Changes in draft 0.7.7

Added section on backplane termination in TCM-CP/JEP

8.5 Changes in draft 0.8

Component detail changes in section 3.2.1 – Timing. Change to 20 TTC signal copies for CP/JEP backplane.

8.6 Changes in draft 0.9

These changes come from the TCM FDR, and references are to the FDR report.

1b. Latch loss of TTC optical signal. Change TTC status to TTC signal loss in status register and front panel, add reset bit in control register. (sec 5.1, and prog model)

2b. Add capacitor decoupling for CAN_GND signal and separate DC-DC converter for optical coupler (sec 5.3.1).

2c. Increase CAN/Test memory depth to 2kBytes (5.8.4.7)

2e. Add CANbus watchdog timer (5.3.2 and status register bit added).

3a. Set VME crate numbers by solder pads in supplementary backplane (3.2.4).

5A. Revised numbers of modules to manufacture (section 3).

Table 2 – incorrect coding of crate numbers corrected.

Fig3 – Only show VME or VME—as appropriate.

Supplementary. Backplane extends to slot 2, feeding 19 TTC signals via J0.

Added description of VME /Test/CAN memory and statement on arbitration.

Defined extra (non-connected) pins for PPM Aux backplane. Fixed numbers to manufacture.

Added holes to dismount aux PPM backplane.

Updated VME—termination values.

Clarify CAN plug/socket arrangements.

8.7 Changes in Version 1.0

Minor text errors corrected.

DCS Local control workstation shared between Level-1 Calo, muon and CTP.

Note that aux backplane pinouts are viewed from rear of backplane.

Correct Aux backplane CANbus tracking and termination to 120 ohm

Update Aux Backplane TTC connectivity in Appx 4 to avoid track crossing

Use different Module-ID numbers for the TCM-VME and TCM-CP/JEP

8.8 Changes in Version 1.05

Upodated table 2 to show connctision for crate numbers 14 & 15 for ROD crates.

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Appendix A TCM-CP/JEP backplane pin-out (Version 1.0)

Pos.	A	B	C	D	E
------	---	---	---	---	---

Guide Pin (0-8mm) (AMP parts 223956-1, 223957-1, or equivalent)

Connector 1 (8-46mm) Type B-19 connector (long through-pins)

1		<G>	VMED00	VMED08	VMED09
2		VMED01	VMED02	VMED10	VMED11
3			VMED03	VMED12	VMED13
4		VMED04	VMED05	VMED14	VMED15
5		<G>	VMED06	VMEA23	VMEA22
6		VMED07	<G>	VMEA21	VMEA20
7		<G>	VMEDS0*	<G>	<G>
8		VMEWRITE*	<G>	VMEA18	VMEA19
9			VMEDTACK*	VMEA16	VMEA17
10		VMEA07	VMEA06	VMEA14	VMEA15
11		<G>	VMEA05	VMEA12	VMEA13
12		VMEA04	VMEA03	VMEA10	VMEA11
13		<G>	VMEA02	VMEA08	VMEA09
14		VMERESSET*	VMEA01	<G>	<G>
15					
16					
17					
18					
19	GEOADD6	GEOADD5	GEOADD4		

Connector 2 (286-336mm) Type B-22 connector (long through pins)

1					
2			<G>	TTC1+	TTC2+
3			<G>	TTC1-	TTC2-
4			<G>	TTC3+	TTC4+
5			<G>	TTC3-	TTC4-
6			<G>	TTC5+	TTC6+
7			<G>	TTC5-	TTC6-
8			<G>	TTC7+	TTC8+
9			<G>	TTC7-	TTC8-
10			<G>	TTC9+	TTC10+
11			<G>	TTC9-	TTC10-
12			<G>	TTC11+	TTC12+
13			<G>	TTC11-	TTC12-
14			<G>	TTC13+	TTC14+
15			<G>	TTC13-	TTC14-
16			<G>	TTC15+	TTC16+
17			<G>	TTC15-	TTC16-
18			<G>	TTC17+	TTC18+
19			<G>	TTC17-	TTC18-
20	<G>	<G>	<G>	TTC19+	TTC20+
21	CAN+	<G>	<G>	TTC19-	TTC20-
22	CAN-	<G>	<G>		

Connector 3 (336-361mm) Type D (N) connector

2	+3.3V (not used on this module)
6	Power GND
10	+5.0V

Appendix B VME J0 backplane connector layout

Appendix B.1 Slot-21 Connector

The slot 21 connector should be fully populated with pins. Pins in the shaded area must not be connected.

Pin	Row f	Row e	Row d	Row c	Row b	Row a	Row Z
1	GND						GND
2	GND				GA<8>		GND
3	GND				GA<7>		GND
4	GND	TTC1+	TTC7+	TTC13+	GA<6>	TTC19+	GND
5	GND	TTC1-	TTC7-	TTC13-	GA<5>	TTC19-	GND
6	GND	TTC2+	TTC8+	TTC14+			GND
7	GND	TTC2-	TTC8-	TTC14-			GND
8	GND	TTC3+	TTC9+	TTC15+			GND
9	GND	TTC3-	TTC9-	TTC15-			GND
10	GND	TTC4+	TTC10+	TTC16+			GND
11	GND	TTC4-	TTC10-	TTC16-			GND
12	GND	TTC5+	TTC11+	TTC17+			GND
13	GND	TTC5-	TTC11-	TTC17-			GND
14	GND	TTC6+	TTC12+	TTC18+			GND
15	GND	TTC6-	TTC12-	TTC18-			GND
16	GND	CAN-	CAN+				GND
17	GND						GND
18	GND						GND
19	GND						GND

View from rear of crate (behind backplane).

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Appendix B.2 Connector at slots 2-20 in ROD crates.

The ROD-Crate auxiliary backplane connectors in slots 2 and 10 should be fully populated with pins, auxiliary backplane connectors in all other slots (except slot 21) should have all pins removed except in the rectangle bounded by 8e, 8c, 16e, and 16c. . Pins in the shaded area must not be connected.

Pin	Row f	Row e	Row d	Row c	Row b	Row a	Row Z
1							
2							
3							
4							
5							
6							
7							
8			GND				
9		GND	TTCrx+	GND			
10		GND	TTCrx-	GND			
11			GND				
12		GA<8>					
13		GA<7>					
14		GA<6>		GND			
15		GA<5>	GND				
16		CAN-	CAN+	GND			
17							
18							
19							

View from rear of crate (behind backplane).

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Appendix B.3 Connector at slots 2-20 in PPM crates.

The PPM-Crate auxiliary backplane connectors in slots 2 and 10 should be fully populated with pins, auxiliary backplane connectors in all other slots (except slot 21) should have pins removed. Pins in the shaded area must not be connected. Signals in the shaded area are specific to the PPM and are not described in this document.

Pin	Row f	Row e	Row d	Row c	Row b	Row a	Row Z
1		+5V	+5V	+5V	+5V	+5V	
2				+5V			
3							
4		Cpld1_TMS	Cpld2_TMS	Jtag_TMS			
5		Cpld1_TCK	Cpld2_TCK	Jtag_TCK			
6		Cpld1_TDI	Cpld2_TDI	Jtag_TDI			
7		Cpld1_TDO	Cpld2_TDO	Jtag_TDO			
8			GND	Jtag_TRST			
9		GND	TTCrx+	GND			
10		GND	TTCrx-	GND			
11			GND	CANPwrOff			
12		GA<8>	CANRxD	LEDCanOff			
13		GA<7>	CANTxD	LEDCan+5V			
14		GA<6>	CANDTR	GND			
15		GA<5>	GND	SYSClk			
16		CAN-	CAN+	GND			
17							
18							
19							

View from rear of crate (behind backplane).

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Appendix B.4 Backplane Connectivity

Signal Source		Signal Destination		
Slot 21 Pins	Name	Slot	Pins	Name
16e, 16d	CAN-, CAN+	All, 2-20	16e,16d	CAN- & CAN+
2b, 3b, 4b, 5b	GA<8>, GA<7>, GA<6>, GA<5>	All, 2-20	12e, 13e, 14e, 15e	GA<8>, GA<7>, GA<6>, GA<5>
4e,5e	TTC1+,-	2	9d,10d	TTCrx+,-
6e,7e	TTC2+,-	9	9d,10d	TTCrx+,-
8e,9e	TTC3+,-	15	9d,10d	TTCrx+,-
10e,11e	TTC4+,-	20	9d,10d	TTCrx+,-
12e,13e	TTC5+,-	14	9d,10d	TTCrx+,-
14e,15e	TTC6+,-	8	9d,10d	TTCrx+,-
4d,5d	TTC7+,-	3	9d,10d	TTCrx+,-
6d,7d	TTC8+,-	10	9d,10d	TTCrx+,-
8d,9d	TTC9+,-	16	9d,10d	TTCrx+,-
10d,11d	TTC10+,-	19	9d,10d	TTCrx+,-
12d,13d	TTC11+,-	13	9d,10d	TTCrx+,-
14d,15d	TTC12+,-	7	9d,10d	TTCrx+,-
4c,5c	TTC13+,-	4	9d,10d	TTCrx+,-
6c,7c	TTC14+,-	11	9d,10d	TTCrx+,-
8c,9c	TTC15+,-	17	9d,10d	TTCrx+,-
10c,11c	TTC16+,-	18	9d,10d	TTCrx+,-
12c,13c	TTC17+,-	12	9d,10d	TTCrx+,-
14c,15c	TTC18+,-	6	9d,10d	TTCrx+,-
4a, 5a	TTC19+,-	5	9d,10d	TTCrx+,-

All (GND) Ground signals should be connected to the backplane ground plane.

Terminate CAN-, CAN+ behind or adjacent to slot 2.

Appendix C CANbus controller programming socket

Signal Name	Pin Number	Description
DCD	1	data carrier detect – Not used
RxD	2	receive data – RS232 out
TxD	3	transmit data – RS232 in
DTR	4	data terminal ready
GND	5	Ground – see under grounding
DSR	6	data set ready
RTS	7	request to send – connect to pin 8
CTS	8	clear to send – connect to pin 7
	9	Not Connected