# RD12 - Timing, Trigger and Control (TTC) Systems for LHC Detectors

**(http://www.cern.ch/TTC/intro.html)**
**Last updated: 27 January 1998 by B.G. Taylor**


Optical Timing Distribution System (Greenwich, 1833)

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Your feedback is invited.

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**TTC Workshop**

A one-day TTC Workshop (Alternative .ps file) was held at CERN on 30 October 1996 to review the

TTC requirements of the LHC experiments, identify common elements, report current progress and plan future work. Copies of the Workshop Record have been sent to all registered attendees and may be requested by e-mail by others.

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**Documents**

From this page you can review some aspects of the RD12 TTC System specified in -

- The ATLAS Technical Proposal (sec. 5.3.4)
- The CMS Technical Proposal (sec. 9.4.5) (Alternative .ps file)
- The LHC-B Letter of Intent (sec. 11.3.3)

and considered a likely solution in -

- The ALICE Technical Proposal (sec. 10.3.1)

The current status of the work is reviewed in the Status Report on the RD-12 Project (Alternative .ps file), CERN/LHCC 97-29, 30 April 1997.

A shorter but less up-to-date overview is given in the paper "TTC Distribution" (Alternative .ps file) presented at the First Workshop on Electronics for LHC Experiments, Lisbon, 11-15 September 1995 (Proceedings CERN/LHCC/95-56, 1 October 1995, pp. 180-184).

Draft specifications for the TTCvi VMEbus interface module are given in the RD12 working document "TTC-VMEbus Interface (TTCvi)" (Alternative .ps file).

Descriptions of the TTCrx timing receiver ASIC are given in the paper "Receiver ASIC for Timing, Trigger and Control Distribution in LHC Experiments" (Alternative .ps file), presented at the IEEE Nuclear Science Symposium, San Francisco, 21-28 October 1995, and "TTCrx, an ASIC for Timing, Trigger and Control Distribution in LHC Experiments" (Alternative .ps file), presented at the Second Workshop on Electronics for LHC Experiments, Balatonfured, 23-27 September 1996.

Technical specifications of the TTCrx are given in the "TTCrx Reference Manual" (no .ps file available).

Some aspects of the proposed TTC system implementation for ATLAS are described in a Trigger-DAQ Steering Group Requirement Document (Alternative .ps file) and the system is intended to meet the requirements specified in the ATLAS ROB User Requirements Document.

The timing resolution required for the ATLAS MDT system is discussed in ATLAS Muon Note 111.

The timing distribution and clock management of FERMI via the service ASIC is discussed in FERMI Note 21.

Special requirements apply to the TTC system for the ALICE TOF detector if Pestov counter technology is chosen.

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**RD12**

Following the Research Board endorsement of an LHCC recommendation in 1995, RD12 was restructured to concentrate only on TTC system development.

The present RD12 collaboration (Alternative .ps file) includes TTC representatives from ALICE, ATLAS, CMS and LHC-B as well as CERN ECP/CMD, ECP/CME, ECP/EDU and ECP/MIC Groups, Rutherford Appleton Laboratory, the FERMI project and additional industrial optoelectronics and micromechanics partners Honeywell Ltd and Lemo SA.

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**Introduction**

The overall TTC system architecture provides for the distribution of synchronous timing, level-1 trigger, and broadcast and individually-addressed control signals, to electronics controllers with the appropriate phase relative to the LHC bunch structure, taking account of the different delays due to particle time-of-flight and signal propagation.

Within each trigger distribution zone, the signals can be broadcast from a single laser source to more than a thousand destinations over a passive network composed of a hierarchy of optical tree couplers. The optical couplers have small size, low mass and unlimited bandwidth. They require no operating power and are potentially highly reliable.

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**Transmitters**

The TTC transmitter crate includes a high-power laser transmitter incorporating a 1310 nm laser head module. At this wavelength the chromatic dispersion of normal optical fibre is negligible. The timing reference can be recovered from the received encoded signal sequence with a jitter of about 50 ps rms relative to the LHC clock input, when transmitting PRBS data with an optical fanout of 1:1000. A lower cost mini-crate system is also available which can be used to generate compatible signals for development work.

The present single-transmitter crates allow the testing of individual sub-detector assemblies at dispersed locations. More compact packaging, integrating the TTC transmitters for several distribution zones in each crate, will be adopted for the final systems.

Several TTC transmitter crates have been supplied and a new batch is currently in production for delivery in early 1998.

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**Encoding**

The transmitter crates incorporate a 160.32 MBaud biphase mark encoder which time-division multiplexes 2 channels using a balanced DC-free code. The primary PLL plus encoder jitter when transmitting PRBS data is about 7 ps rms. A narrow bandwidth PLL with a low-noise VCXO having low sub-harmonic feedthrough allows an rms output jitter of less than 10 ps to be maintained with an input LHC reference jitter of several hundred ps.

The low-latency A-channel is dedicated to the transmission of level-1 trigger accepts. The B-channel transmits framed and formatted broadcast and individually-addressed commands and data using forward error-correction for high reliability. The format supports up to 16K receivers per distribution zone, each of which may be associated with up to 256 internal and external subaddresses.

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**TTCvi**

The TTC transmitter encoders are driven by VMEbus modules which allow programmable selection of trigger source and synchronous signal timing relative to the LHC machine orbit. The TTC-VMEbus interface (TTCvi) which is being developed by CERN ECP/EDU Group can be accessed by multiple VMEbus masters including interfaces to the detector control system or a local workstation. It includes a programmable trigger emulator and pseudo-orbit generator for test purposes.

Draft specifications for the TTCvi are given in the RD12 working document "TTC-VMEbus Interface (TTCvi)" (Alternative .ps file) by Ph. Farthouat and P. Gällnö.

A first prototype TTC_Test module with reduced functionality is currently available. The design of the full TTCvi has been completed, prototypes are being tested and a small initial production is foreseen for early 1998.

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**RD12 connector**

Since conventional optical single-fibre connectors and optoelectronic receivers are bulky, a subminiature optical fibre connector and active device mount has been developed which allow timing receivers to be much smaller than telecommunications components. This "RD12" connector, which is now entering industrial production by Lemo SA, is quite tiny compared with the MU type, the smallest currently available standard design single-fibre connector which is a miniature version of the SC type. A subminiature connector-connector coupling bush has also been developed.

A first prototype batch has successfully undergone qualification tests specified by Boeing for airborne applications. Preliminary data sheets are available from B.G. Taylor or the Lemo website.

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**Photodiode + preamplifier**

The hermetically-packaged InGaAs PIN photodiode + preamplifier has a bandwidth of 160 MHz and is rated for 0-100 deg C operation. The sapphire-lensed component is actively aligned in the ST or RD12 device mount to ensure maximum responsivity.

The Si bipolar preamp design features a second amplifier for the cancellation of power supply noise. It has so far been tested to a total dose of 20 Mrad without significant performance degradation and further irradiation tests are planned.

Production quantities of the ST version and prototypes of the RD12 version of the PIN+Preamp are currently available. Other PIN+Preamp components are being evaluated to allow a choice of cost/performance trade-off.

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**TTCrx**

A timing receiver ASIC (TTCrx) which delivers the TTC signals to front-end electronics controllers is being developed by the CERN Microelectronics Group. The TTCrx, which is packaged as a compact 15x15mm Ball Grid Array, can deliver the full range of decoded and deskewed signals, including synchronous commands and 12-bit bunch numbers and 24-bit event numbers matched with each level-1 trigger accept. The TTCrx incorporates a serial output for driving a reduced-functionality receiver for use in inner detector front-end electronics where low mass and power consumption are particularly critical.

Descriptions of the TTCrx are given in the papers "Receiver ASIC for Timing, Trigger and Control Distribution in LHC Experiments" (Alternative .ps file), J. Christiansen, A. Marchioro, P. Moreira and A. Sancho, presented at the IEEE Nuclear Science Symposium, San Francisco, 21-28 October 1995, (published in IEEE Trans. Nuclear Science, vol. 43, June 1996, pp. 1773-1777) and "TTCrx, an ASIC for Timing, Trigger and Control Distribution in LHC Experiments" (Alternative .ps file), J. Christiansen, A. Marchioro and P. Moreira, presented at the Second Workshop on Electronics for LHC Experiments, Balatonfured, 23-27 September 1996.

Detailed technical specifications of the TTCrx are given in the "TTCrx Reference Manual" (no .ps file available), J. Christiansen, A. Marchioro and P. Moreira.

A number of prototype TTCrx ASICs has been fabricated through CMP and they can now be supplied to users in the BGA package. A small test carrier PC board is available which supports the TTCrx and associated components such as the PIN+Preamp.

Migration of the TTCrx design to DMILL radiation-hard technology is in progress. The analogue parts of the design have already been submitted for fabrication and the complete rad-hard TTCrx should be available in late 1998. In the DMILL version of the TTCrx ASIC the JTAG controller will be replaced by an I2C bus interface. This interface will allow an external I2C controller to write and read all the TTCrx internal registers and will replace the boundary scan functionality for testing the I/O pins. An initialization PROM will no longer be required for this new version, which will also support more user-defined broadcast codes and have lower trigger latency.

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**TTCsr**

A TTC simple receiver (TTCsr) board is being developed by CERN ECP/EDO Group as a PCI Mezzanine Card (PMC) for the convenience of users carrying out development work before directly integrating the TTCrx ASICs in their electronics. The TTCsr provides some of the TTCrx signals as IEC 912 ECL front-panel outputs, and includes FIFOs to buffer TTCrx data to the PCI bus.

A preliminary TTCsr Specifications Manual will be available shortly.

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**Synchronisation**

While the gaps in the LHC bunch structure reduce the machine filling factor by about 20%, they may prove useful for adjusting the synchronisation by crosscorrelation with the event occurrence patterns. A draft CMS Note on A method for synchronization of the trigger data (.ps file only) has been written by J. Varela.

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**Error correction and recovery**

The TTC system employs Hamming checkbits which allow the automatic forward error correction by the TTCrx ASIC of all single-bit and the detection of all double-bit errors, as well as many others.

Owing to the large number of channels and the inaccessibility of the front-end electronics for repair, a number of TTC channels may be expected to be defective. DAQ Note 45 (Alternative .ps file) by N. Ellis discusses ideas for error detection and recovery in ATLAS readout systems.

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**TTC at Level 2/3**

In addition to the primary application of broadcasting signals to the front-end electronics controllers, the use of the TTC system is being studied for other possible applications, such as:

- The broadcasting of event flow control information from the event manager to the readout DPMs at CMS (about 1024 destinations for event scheduling and filter task control)
- The broadcasting of Level 2 requests and results to the ROBs in the Level 2 trigger demonstrator programme (Alternative .ps file) of ATLAS

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**Shortcuts to related topics:**

- LHC
- ALICE
- ATLAS Trigger/DAQ
- CMSINFO
- LHC-B
- The RD-27 project
- Optoelectronics News from Laser Focus World
- New lightwave components

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**Appendix: file format alternatives**

Acrobat Reader software for viewing and printing the TTC document files in **.pdf format** is available here for Macintosh, Windows, SPARC, HP, SGI and DOS platforms. The Acrobat Reader, which is free of charge, provides many facilities for viewing .pdf documents with scanning, zooming, caching, tiling, colour graphics, bookmarks, thumbnails, searching and selective text and graphics copying.

Alternative files in **.ps format** have been provided in most cases, but they are usually longer to download and can’t be viewed on a Macintosh screen (though they can be printed on a LaserWriter).

In case of difficulty, paper copies of any of the TTC documents are available from B.G. Taylor.

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