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Gemini Controls Group Interface Control Document

ICD 9 - EPICS Time Bus Driver

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This report defines the EPICS and VxWorks interfaces to the Gemini Time Bus system.

1.0 Introduction

1.1 Purpose

This document describes the device driver software required to interface EPICS to the Bancomm bc635 and bc637 Time Bus VME cards. This software forms part of the Gemini Standard Instrument Controller workpackage, described in the Gemini document SPE-C-G0023.

Intended Readership:

- Gemini Work Package Developers
- Gemini Software and Controls Group

1.2 Scope

This document describes the EPICS Driver Support, EPICS Device Support and VxWorks software available to use with the Bancomm bc635 or bc637 VME cards.

The software provides the following facilities for EPICS records:

- Read the current time on request.
- Trigger I/O interrupt and time report on an external event
- I/O interrupt at a specified time of day.
- Accurate periodic interrupts to drive the system clock and thus initiate database processing at precise intervals.
- Accurate EPICS processing timestamps.

The software will thus provide a comprehensive time service for a suitably equipped IOC.

Section 4.0 on page 11 of this document provides details of low level calls that can be made to the Bancomm hardware directly from C code. Developers should not use these calls directly but instead use the higher level library provided as part of the TCS Time System. Full details of the TCS Time System can be found in [8] and [9].

1.3 Applicable Documents

[1] SPE-C-G0023, *SIC WPD*, Gemini 8m Telescopes Project

[2] SPE-C-G0014, *Gemini Software Requirements Spec*, Gemini 8m Telescopes Project

[3] *Synchronized Time Stamp Support*, Argonne National Laboratory

[4] GSCG.grp.017, *Glossary*, Gemini 8m Telescopes Project

[5] *bc635VME Time and Frequency Processor Operation and Technical Manual*, Bancomm Division of Datum Inc.

[6] *bc637VME GPS Satellite Receiver Addendum*, Bancomm Division of Datum Inc.

[7] *Network Time Protocol specification and implementation.* DARPA Network Working Group Report RFC-1119.

[8] *tcs_cjm_034, The TCS Time System*, C. Mayer, D. Terrett & P. T. Wallace

[9] *tcs_ptw_006, Time*, P. T. Wallace

1.4 Definitions, Acronyms and Abbreviations

GPS	Global Positioning System: uses a network of satellites to provide accurate position and time information.
IRIG-B	Inter-Range Instrumentation Group - Time Format B
MJD	Modified Julian Date = JD - 2400000.5
NTP	Network Time Protocol (an Internet standard)
RTC	Real Time Clock
TAI	International Atomic Time
TOD	Time-of-Day
UTC	Co-ordinated Universal Time

See document [4] Glossary for additional acronyms and terms used by the Gemini ICDs.

2.0 General Description

This section gives an overview of the device driver software, putting it into context within the Standard Instrument Controller system as a whole.

For further background on timescales and clocks available for use on the Gemini systems, refer to the later section of this document entitled *Hitchhikers Guide to Timescales and Gemini Clocks.*

2.1 Product Perspective

The Time Bus driver forms part of the Gemini Standard Instrument Controller workpackage, and implements an interface between EPICS and a Bancomm GPS/IRIG-B card installed in the IOC. The other new software components of the Standard Instrument Controller development are:

- DeltaTau DC Motor Control driver
- VMIC Reflective Memory bus driver
- Allen-Bradley PLC Communications Interface
- Sample Control System

Of these, only the Sample Control System has any direct interaction with the Time Bus driver — it provides a demonstration and test facility for the other components of the SIC, and contains an EPICS database. Other drivers should not interact directly with the Time Bus driver in any way for the following reasons:

- All such interaction should be controlled via the EPICS database
- Some IOCs will not have any Time Bus hardware installed
- It is desirable to be able to create an EPICS system which does not load unnecessary drivers

2.2 Product Functions

The aim of Time Bus driver development is to provide a means for the current time to be made available to an EPICS database as accurately as possible, utilizing the special-purpose hardware installed in the IOC.

2.2.1 Hardware

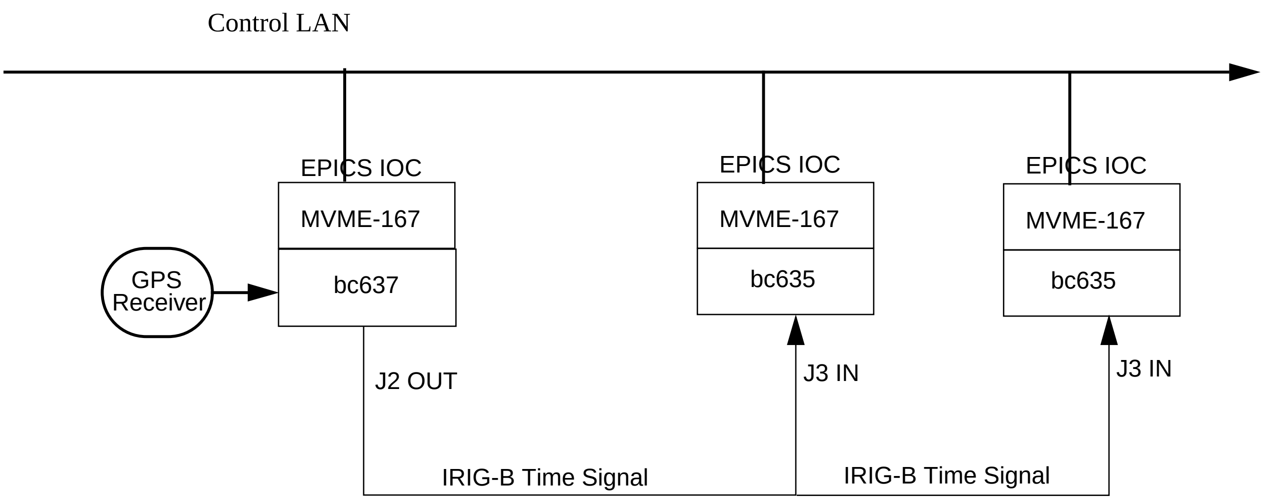
There are two types of IOC on the Time bus: Master and Slave IOCs. See Figure 1 below for a schematic representation of the Bancomm 635 and 637 card locations and Time Bus connections.

- Time Master IOC

  This IOC is the only one containing a Bancomm bc637VME card, which is a Bancomm bc635VME card incorporating a GPS Satellite Receiver module. The IOC is thus the time master and knows the current time with the highest accuracy. It generates IRIG-B time codes for other IOCs. In the event of a failure of the incoming GPS signal, the bc637VME card will maintain an approximation to the current accurate time by freewheeling, and will continue generating IRIG-B time code.
- Time Slave IOC

  This IOC contains a Bancomm bc635VME card (with no GPS receiver) which is connected to a Time Master IOC. This IOC is thus an IRIG-B Time Slave, and will synchronize to the incoming IRIG-B Time code. In the event of a failure of the incoming IRIG-B signal, the bc635VME card will maintain an approximation to the current accurate time by freewheeling.

FIGURE 1. Hardware Architecture



2.2.2 Software Facilities

- Accurate time is available to the EPICS database of the IOC using device and driver support which permit the current time to be read from an input record of a suitable type.
- The time may be returned using either the TAI or UTC timescales. The TAI timescale has no discontinuities, unlike those which occur as UTC leap seconds. The TAI timescale is determined by applying a fixed offset to the GPS timescale read by the bc637 GPS receiver.
- The Bancomm card can be requested to produce an interrupt at a specified precise time of day. An EPICS I/O interrupt will be generated, which may be used to initiate database processing. Only one time of day interrupt may be specified at any one time.
- Support will be provided for the connection of external hardware event signal to the Bancomm card. The incoming signal causes the value of the time to be latched and can then be read from the supporting database record.
- The Bancomm can output periodic interrupts at a specified, configurable, rate. This is utilized to drive the VxWorks system clock. Periodic database scanning is driven by the system clock and database processing will therefore occur at precise intervals.

- A user written interrupt service routine may be supplied which will be executed on each periodic interrupt.
- The internal EPICS database processing timestamp value is derived from the Bancomm time. The internal format of the timestamp is unchanged from previous EPICS releases.

2.3 User Characteristics

Users of the driver will fall into one of the following categories:

- Work Package Developer
- Gemini Operations Maintenance staff

The characteristics of these users are described below

2.3.1 Work Package Developer

Gemini Applications Developer as described in SRS section 4.3.4.1.

2.3.2 Gemini Operations Maintenance staff

As described in SRS section 2.5.2.3.

2.4 General Constraints

The software development work which this specification describes shall conform to the general constraints and requirements set out in the Work Package Description for the Standard Instrument Controller. This in turn requires conformance to the Gemini Software Requirements Specification.

2.5 Assumptions and Dependencies

This specification has been based on the assumptions listed below. If any of these prove to be invalid, the relevant parts of this document can no longer be relied upon to accurately describe the requirements of the driver software.

2.5.1 IRIG-B Accuracy

The IRIG-B time signal is generated accurate to +/-10 microseconds. It is assumed that it is sufficiently accurate for the purposes of the Gemini system after distribution delays, etc.

For the highest accuracy, compensation may be applied for the propagation delay in the IRIG-B signal. A configuration parameter allows this compensation value to be specified in microseconds. See the section below describing *Bancomm Card Configuration*.

2.6 Communication Architecture

The Time Bus client and server IOCs communicate via the IRIG-B time bus and the Control LAN.

3.0 Implementation: EPICS Interface

This section describes how the SIC Time Bus facilities are implemented using EPICS database records and VxWorks procedure calls.

Note that, from a software point of view, the Bancomm 635 and 637 VME cards can be considered identical. The bc637 differs from the bc635 only by additionally incorporating a GPS receiver module. For brevity in the following description, when a Bancomm 635 card is referred to, a bc637 card is also implicitly included. The only recognised EPICS Bancomm device type is Bancomm 635 - this device type should also be used with a bc637 card.

3.1 EPICS Input Records Summary

Facility	Record Type	Signal	Input Value
Read Current time from Bancomm	ai	N/A	Current time as real number of seconds
Read time of External Event	ai	1	Time of external event signal
Read time of Time-Of-Day interrupt	ai	3	Time that TOD interrupt occurred

3.2 EPICS Output Record Summary

Facility	Record Type	Signal	Output Value
Set time for Time-Of-Day Interrupt	ao	3	Time when interrupt will occur

3.3 Read Current Time

3.3.1 Purpose

Read the current time directly from the Bancomm bc635 VME card

3.3.2 EPICS Record Details

- EPICS Analog Input (ai) record.
- Device type (DTYP field) must be Bancomm 635.
- Input specification (INP) field:
  - Card number zero
  - Signal value zero (unused)
- Scan mechanism (SCAN) field may *not* be I/O Intr.

3.3.3 Returned Value

The time is returned in the VAL field of the record. Field type is DOUBLE.

3.3.4 Units and precision

The time is returned as a real number of seconds relative to the Unix Epoch (1 Jan 1970). See below for further discussion of standard time scales and epoch. The time will correspond to UTC if GPS leap seconds are being used: if not the time will be offset from UTC by the current number of GPS leap seconds plus the GPS to TAI offset.

The DOUBLE value in an EPICS database record is in IEEE floating point Double Format with 52 bits in the fractional part. This corresponds to a precision of approximately 1 microsecond in the 30 year period since the epoch.

The time value in the Bancomm internal registers is stored with a precision of 100 nanoseconds. The specified absolute accuracy of the Bancomm hardware is ±10 microseconds.

3.3.5 Processing

The time is read from the Bancomm VME card whenever the record is processed, triggered by any of the EPICS scanning mechanisms. The time value is latched at the point of entry to the Bancomm driver support code and subsequently converted to the required format returned in the EPICS record.

3.3.6 Read Alarms

The following alarms may be set when the record is processed (the alarms have alarm status READ_ALARM):

- **INVALID** alarm, when the time read appears to be an illegal time value. The data returned in the VAL field should be assumed to be invalid. This could be due to a Bancomm hardware error or (more likely) the VxWorks crate containing the card has been rebooted and there is no reference input for the Bancomm e.g. master crate reboot during GPS failure or slave crate reboot with no IRIG-B input.
- **MAJOR** severity alarm. The time is not locked to the reference source: the GPS receiver (master IOC) or IRIG-B input (slave IOC). It can be assumed that the time is freewheeling in this case, using the last known reference frequency. This may be a transient state that does not seriously affect the accuracy of the time - however the alarm should not be ignored as it may indicate a genuine hardware problem.

  For a master crate the alarm occurs whenever the GPS cannot get sufficient satellite fixes, or the GPS receiver is disconnected or has failed. For a slave crate, the IRIG-B input may be disconnected or failed: this occurs whenever the master crate is rebooted.
- **MINOR** severity alarm, when the accuracy of the time is less than the best accuracy that the Bancomm card can achieve. In fact, the time value returned in the VAL field will probably be valid and the accuracy probably within acceptable limits. Either of the following conditions can set this alarm:
  - The input reference source time is offset relative to the current internal time (> 5 microsecs).
  - The Bancomm internal oscillator frequency is offset from the input reference source frequency. This state persists for some time (up to 20 minutes) after changing or reconnecting the input reference source, whilst the Bancomm gradually adjusts its frequency.

3.4 Set Time-of-Day Interrupt

3.4.1 Purpose

Specify a time when the Bancomm card is to generate an interrupt. This interrupt (a Time-of-Day or TOD interrupt) may be set to occur up to 24 hours in advance.

3.4.2 EPICS Record Details

- EPICS Analog Output (ao) record.
- Device type (DTYP field) must be Bancomm 635.
- Output specification (OUT) field:
  - Card number zero
  - Signal value 3
- Scan mechanism (SCAN) field must be passive.

3.4.3 Output Value

The value written in the VAL field is a type DOUBLE real number representing the required time for the TOD interrupt.

3.4.4 Units and precision

The output value is a real number containing the number of seconds since midnight at the time of the required TOD interrupt. The specified time must be in the range 0.0 (midnight) to 86399.999 (23h59m59.999s) inclusive.

The interrupt time will be accurate to within 1 millisecond of the time specified. For example, setting the VAL field to 82943.832145 will cause an interrupt to occur at 23h 02m 23.832s ±1 msec. The time specified should correspond to UTC if GPS leap seconds are being used: if not the time should be offset from UTC by the current number of GPS leap seconds plus the GPS to TAI offset.

3.4.5 Processing

The interrupt time is set in the Bancomm VME card whenever the output record is processed. The STROBE1-3 registers in the Bancomm card are loaded with the supplied time value.

3.4.6 Write Alarm

The following alarm may be set when the record is processed (the alarm has alarm status WRITE_ALARM):

- **INVALID** alarm, when the specified time for the interrupt is an out-of-range time value. The specified time must be in the range 0.0 (midnight) to 86399.999 (23h59m59.999s) inclusive.

3.5 Read Time of Time-of-Day Interrupt

3.5.1 Purpose

Read the time when the Bancomm card generated a Time-of-Day interrupt.

3.5.2 EPICS Record Details

- EPICS Analog Input (ai) record.
- Device type (DTYP field) must be Bancomm 635.
- Input specification (INP) field:
  - Card number zero
  - Signal value 3
- Scan mechanism (SCAN) field must be I/O Intr.

3.5.3 Returned Value

The time is returned in the VAL field of the record. Field type is DOUBLE.

3.5.4 Units and Precision

The time is currently returned as a real number of seconds relative to the Unix Epoch (1 Jan 1970). See section above describing reading current time for further details.

The time will correspond to UTC if GPS leap seconds are being used: if not the time will be offset from UTC by the current number of GPS leap seconds plus the GPS to TAI offset.

The time value in the Bancomm internal registers is stored with a precision of 100 nanoseconds. The absolute accuracy is approximately ±10 microseconds.

3.5.5 Processing

The record is processed when a Time-of-Day interrupt occurs on the Bancomm card. Processing then proceeds as described above to read the current time.

3.5.6 Alarms

As described above for Read Current Time

3.6 Read Time of External Event Input

3.6.1 Purpose

Read the time and cause record processing when the Bancomm card receives an external event input signal.

3.6.2 EPICS Record Details

- EPICS Analog Input (ai) record.
- Device type (DTYP field) must be Bancomm 635.
- Input specification (INP) field:
  - Card number zero
  - Signal value 1
  - Parameter string + or - for rising or falling edge respectively.
- Scan mechanism (SCAN) field must be I/O Intr.

3.6.3 Returned Value

The time is returned in the VAL field of the record. Field type is DOUBLE.

3.6.4 Units and Precision

The time is currently returned as a real number of seconds relative to the Unix Epoch (1 Jan 1970). See section above describing reading current time for further details.

The time will correspond to UTC if GPS leap seconds are being used: if not the time will be offset from UTC by the current number of GPS leap seconds plus the GPS to TAI offset.

The time value in the Bancomm internal registers is stored with a precision of 100 nanoseconds. The absolute accuracy is approximately ±10 microseconds.

3.6.5 Processing

3.6.6 The record is processed when the input to the external event signal on the Bancomm card changes. If the INP field parameter string starts with a '-' character the trigger occurs on the falling edge of the signal, otherwise the rising edge is used. This causes an interrupt, and processing then proceeds by reading the event time and converting it exactly as for Read Current Time.

3.6.7 Alarms

As described above for Read Current Time, except the status returned is that at the time of the event, not when the record was processed (there will usually be a few microseconds between these two moments).

3.7 EPICS TImestamps

Each time an EPICS record is processed, the timestamp field for that record is updated with the current time. Every record has the timestamp field, field name TIME, which consists of two long words containing the time in seconds and nanoseconds past the EPICS Epoch January 1, 1990. Leap seconds are ignored in the seconds count.

The time will correspond to UTC if GPS leap seconds are being used: if not the time will be offset from UTC by the current number of GPS leap seconds plus the GPS to TAI offset.

The EPICS timestamp driver software (drvTS) has been modified to read the time direct from the Bancomm card if possible. If the Bancomm time is unavailable for any reason the timestamp driver maintains its own soft time which is incremented using system clock ticks.

Note that the EPICS Event System as described in the document *Synchronized Time Stamp Support* is *not* used by the Gemini Time Bus software. The Event System depends on special hardware to deliver synchronized event to all IOCs on a network and is not part of the Gemini SIC.

4.0 Implementation: VxWorks Interface

The following sections describe Time Bus facilities which can be called directly using VxWorks procedure calls. As mentioned in the introduction, developers are discouraged from using these calls directly particularly BCconfigure, bc635_read and bcGetGpsLeap. Instead, all access to time from C code should be via the TCS Time System (see [8] and [9]).

The VxWorks interfaces described here provide the following facilities:

- Specify the Bancomm periodic interrupt frequency and the VxWorks system clock rate.
- User written interrupt service routine to be called whenever a periodic interrupt is generated by the Bancomm.
- Read the current time directly.

4.1 Bancomm Card Configuration

BCconfigure(const int MasterIOC, const int NoLeapSecs, const int intPerSecond, const int intPerTick, const int Offset)

4.1.1 Purpose

This is intended to be used in the VxWorks start-up command file for an IOC. The call to BCconfigure should be *before* iocInit and TSConfigure.

- The first parameter defines whether this IOC contains the Bancomm master card (bc637) with a built-in GPS receiver.
- The second parameter defines whether GPS leap seconds are used or not. A value of zero implies that GPS leap seconds *should* be used i.e. time values in the Bancomm will be UTC. A value of one implies that GPS leap seconds should not be used; *i.e.*, returned time values will be TAI.
- The third parameter is the frequency of periodic interrupts to be generated by the Bancomm card.

  If this value is zero then Bancomm periodic interrupts are disabled and the system clock cannot be driven off the Bancomm.
- The fourth parameter allows the VxWorks system clock rate (the ‘tick rate‘) to be set. This is used if the required tick rate is less than the periodic interrupt frequency specified in the third parameter. The value of this parameter is the number of periodic interrupts that will occur for each system clock tick. For example if the value is 2 then the tick frequency will be half that of the periodic interrupts with a system clock tick occurring every other periodic interrupt. A value of 1 or 0 means that the system clock rate is set to be the same as the periodic interrupt rate.

  The Bancomm driver software generates system clock ticks by calling the VxWorks subroutine **tickAnnounce()**. Consult the VxWorks reference manual entry for further details.

- The fifth parameter is an offset in microseconds which can be used to compensate for delays in the time reference input. A positive value compensates for a delay in the input time signal.

4.1.2 Parameters

Name	Type	Description
MasterIOC	integer	If TRUE, this IOC has the Master Bancomm card (bc637)
NoLeapSecs	integer	If TRUE, do not use GPS leap seconds
intPerSecond	integer	Bancomm periodic frequency in Hz
intPerTick	integer	Number of periodic interrupts per system clock tick. If 0, set clock rate to be the same as the interrupt rate.
Offset	integer	Compensation offset in microseconds

4.1.3 Example

BCconfigure(1, 1, 200, 2, 20)

The first parameter defines this IOC as containing the master Bancomm card (bc637). The second parameter states that GPS leap seconds are not to be used. The third parameter specified that the Bancomm time card should generate periodic interrupts at a frequency of 200Hz. The fourth parameter defines the number of Bancomm interrupts per system clock tick to be 2. The VxWorks system clock tick rate will therefore be 200 divided by 2 i.e.100Hz.

The last parameter defines a 20 microsecond offset to be applied to the input time reference: normally this would only be non-zero for a slave card using IRIG-B input time signal.

Note that to use the Bancomm driver, the EPICS Time Stamp system *must* be initialised properly after BCconfigure by calling TSconfigure giving all of its 7 parameters, the seventh of which must be a 1. Failure to do this can result in the IOC not initialising correctly or even crashing.

4.2 Read Bancomm Time Directly

*int bc635_read(double *time)*

4.2.1 Purpose

A VxWorks subroutine call to read the Bancomm time directly. It is documented here for use by high-speed applications.

4.2.2 Parameter

time	Pointer to double	Current time read from Bancomm card

4.2.3 Returned Value

Integer status returned may take the following values:

0 = Time read OK.

-1 = Error. Time value returned is invalid.

or the value of a bit field with bit significance as follows (0 = LSB)

2	1	0
Frequency offset error	Time offset error	Time not synched

The errors indicated for bits 2 or 1 are minor errors whilst bit 0 being set is potentially more serious. For further details regarding these Bancomm error states see the above section entitled Read Alarms: the EPICS alarm corresponding to error bits 1 or 2 is **MINOR** and for bit 0 is **MAJOR.**

4.2.4 Units and precision

The time is currently returned as a real number of seconds relative to the Unix Epoch (1 Jan 1970). Leap seconds since the epoch are *not* included in this count - see below for further discussion of leap seconds and conversion to and from standard time scales.

The value is in IEEE floating point Double Format with 52 bits in the fractional part. This corresponds to a precision of approximately 1 microsecond in the 30 year period since the epoch.

4.3 User Supplied Interrupt Service Routine

This facility is provided for use by high speed interrupt driven applications. A user supplied interrupt service routine is called every time a periodic interrupt is generated by the Bancomm. It will be executed with a frequency equal to the first parameter specified in the call to BCconfigure. The supplied ISR must be declared using the procedure bcIntConnect and may be disconnected by using the procedure bcIntDisconnect.

4.3.1 Connect User Supplied ISR

*void bcIntConnect(void (*isrproc)(const int n))*

The supplied parameter *isrproc* is the name of the user supplied interrupt service routine. The ISR should be declared with a single integer parameter - this value is a running count of the total number of interrupts.

4.3.2 Disconnect User Supplied ISR

void bcIntDisconnect()

This disconnects any previously connected user supplied ISR.

4.4 Get Current GPS Leap Second Value

int bcGetGpsLeap()

This function returns an integer value: the current value of the GPS leap seconds. This value may not necessarily be up to date just after the leap second has occurred.

The value is returned as zero on a slave IOC (i.e. a bc635 card rather than a bc637 with built-in GPS receiver).

5.0 EPICS Environment Variables

The following EPICS environment variable is used by the Bancomm driver. Usually the variable will be defined in a resource definition file whose name is supplied as a parameter to iocInit. To check the current values of EPICS environment parameters use the command epicsPrtEnvParams.

- EPICS_TS_NTP_INET. This value is set to the IP address of a suitable NTP (Network Time Protocol) or Unix time host. NTP time is obtained from this host and is used to provide an independent source of time - in particular it is the only source of the year number. Note that if this host is not on the same network as the IOC then routing information must be supplied using **routeAdd**(). If the value is empty then the boot node IP address is used. See below for further discussion of the use of NTP in conjunction with Time Bus facilities.

6.0 Engineering Commands

Occasionally it may be necessary to send commands directly to the Bancomm time card for configuration or error recovery reasons. This is usually done by means of data packets sent to the TFP (Time and Frequency Processor). The data almost always consist of a sequence of ASCII characters. See the Bancomm *bc635 Operation and Technical Reference Manual* for full details of the available commands.

Such commands must be used with care, as incorrect commands are likely to cause illegal time to be generated.

Facilities for controlling the Bancomm directly are packaged up as VxWorks subroutine calls which can be issued directly from the VxWorks shell. Some of the more useful commands are as follows:

6.1 Send Data to TFP

*bcSendTfp(const char *string)*

This subroutine will send the string pointed to by *string* to the Bancomm TFP. The first character defines the function (**A** - **Q**) and subsequent characters depend on the specific function required. See bc635 Technical Manual for details.

6.1.1 Example

bcSendTfp(“A0”)

This example sends the character 0 (zero) for function type A. This sets the TFP reference time source to be the incoming IRIG-B signal (the default mode for the time card in a slave IOC).

6.2 Load Current Time into RTC using NTP

bcSetRTC()

No parameters. This causes the current time to be fetched over the network from the NTP host and this value to be loaded into the Bancomm on-board Real Time Clock.

The time loaded into the RTC must have an integer number of seconds - no fractional second is allowed. This limits the accuracy of the operation, so the **bcSetRTC()** call tries to set the RTC at a time close to the next second tick. The resulting RTC accuracy is believed to be about 20 milliseconds.

7.0 GPS Failures and RTC Backup Mode

The Bancomm card in the master IOC is a bc637 which includes an Acutime GPS receiver module. The master time synchronization normally uses the GPS signal and distributes time via an IRIG-B signal over the Time Bus. If for any reason the GPS signal fails (perhaps due to an antenna or receiver fault) the master time will free-wheel using the last known reference rate. The status value returned as an EPICS Alarm indicates when the primary reference source is lost.

What happens if the system is rebooted when no GPS signal is available? In this case the Bancomm card can instead make use of a battery backed on-board Real Time Clock (RTC). The Bancomm can be set into a special mode (Mode 3) to use the RTC as its time source. This RTC is not very accurate and so needs to have the correct time loaded into it before RTC mode is selected.

This RTC can be set to a reasonable accuracy (a few milliseconds) by getting the time using NTP (Network Time Protocol) over the network from any NTP host. The vxWorks subroutine **bcSetRTC()** is provided to do this. This routine can be used at any time regardless of the GPS signal status and does not cause the Bancomm to use the RTC as its reference source. If it found necessary to use the RTC in place of the GPS receiver as the primary time source, the Bancomm should be set into RTC mode (3) using the call **bcSendTfp(“A3”)**

8.0 Time Scales and Formats

To make use of accurate time values returned by the Bancomm, three factors need to be known:

- The timescale - whether it is a standard timescale (e.g. UTC) and if not, what is the difference between the returned Bancomm time and the standard timescale.
- The epoch: this is the zero point relative to which the returned Bancomm times are measured.
- The units in which the returned time is measured.

8.1 TImescale

The Bancomm 637 (master) card provides a choice of two different timescales, selectable in hardware. Only the master card provides this choice and, as the time is distributed without further modification via IRIG-B, all slave cards receive the time using the timescale of the master. The timescale is configurable and is selected by a parameter to BCconfigure. It may be either:

- TAI Time. *(Default)* This timescale is a continuous count of Atomic seconds with no leap second discontinuities. It has a fixed, integer offset of 19 seconds from GPS time, which is the base time standard kept by the GPS satellites and read by the Bancomm GPS receiver. Both TAI and GPS timescales are offset from UTC by a variable, integer number of seconds. On Jan 1, 1995, the UTC–GPS offset was 10 seconds.
- UTC. This has a discontinuity at the time of a leap second and is therefore not well suited for precise time applications which need to measure intervals over a leap second. However, UTC is the commonest standard timescale and will be useful in many applications.

8.2 Epoch

The default epoch used for the time returned by the Bancomm driver is “seconds since the Unix Epoch” (January 1, 1970). This enables ANSI standard C routines to be used to convert the integer part of this time value into other formats - for example into a character string using **ctime()** or into a broken-down time structure using **localtime()**. The resulting time will be in the selected Bancomm timescale: when TAI time is used, the UTC-GPS offset must be applied to derive current UTC.

Note that this time value does *not* correspond to the actual number of Atomic seconds that have elapsed since Epoch (1970 January 1). Leap seconds are deliberately ignored, so the true number of elapsed Atomic seconds will be larger than the number returned. For a formal definition of the value “seconds since the Epoch”, as used by ANSI C routines, refer to the standards document POSIX 1003.1.

During a leap second, the UTC time value in this format is ambiguous - the integer part of the time value will be identical at the two successive UTC seconds 23h59m60s and 00h00m00s.

8.3 Units

The time is returned by the Bancomm software as a real number of seconds.

8.4 Additional Time Scales and Formats

Other time scales, epoch and units will be supported in due course: MJD format is a probable addition in the near future.

8.5 Leap Seconds

Leap seconds do not occur when the TAI timescale is used: if UTC is used then the leap seconds introduce ambiguity in the time value as described above. Additional information is needed to enable these to be resolved. In practice, this means knowing in advance the exact time when the leap second will occur.

9.0 Network Time Protocol (NTP) Usage

The Network Time Protocol (defined in Internet Standard document RFC-1119) is a protocol used to distribute time within and between large distributed networks. The NTP primary network is a worldwide set of servers (called Stratum-1 servers) that obtain UTC directly via radio or satellite receivers. A hierarchy of servers below these (Stratum-2,-3 etc.) in turn provide NTP service to any host on the Internet. This hierarchy distributes the server loading and provides redundancy in the event of server failures.

The protocol includes sophisticated algorithms for estimating and correcting network transmission delays and this enables good time accuracy to be maintained even with significant and variable networking overheads. The accuracy depends on the quality of the local clock oscillator but in practice is unlikely to be better than 1 millisecond.

NTP will be used to maintain time on Gemini general purpose Unix workstations but will not be used as the primary time synchronization method for the Gemini Time Bus. It is, however, used in two ways within this system:

- To initialize the year number - this information is not carried by the IRIG-B time signal on the Time Bus.
- To provide a back-up time to set the Bancomm on-board Real Time Clock in the event of persistent GPS failure.

10.0 Performance Requirements

The requirements for time accuracy performance of the time bus software and hardware are as follows:

Pointing (Absolute Time): 3ms RMS.

Tracking (Relative Time): 0.3ms RMS over 1 hour.

However, note that these performance requirements cannot be tested without additional specialised hardware (an independent source of accurate absolute time).

Appendix: Hitchhikers Guide to Timescales and Gemini Clocks

11.0 Timescales

Timescales that are referred to in this document or will be used in the Gemini systems are as follows

11.1 TAI

TAI is International Atomic Time, a precisely determined uniform timescale that is derived from a set of high-precision atomic clocks around the world. Its units are the SI second which is defined in terms of a caesium atom transition. Its units are the same as UTC but is offset from it by an integral number of seconds which increases at each leap second.

11.2 UTC

UTC is Coordinated Universal Time. Its units are the same as TAI (SI seconds) but its values are adjusted by occasional leap seconds to compensate for the variable rate of the earth's rotation. A leap second is inserted to maintain the difference between UTC and UT1 at less than 0.90 seconds (see below for description of UT1). At a leap second, which may occur at the end of June or December, an extra second is inserted at the end of the day. Successive seconds at this time are denoted as 23h59m59s, 23h59m60s and 00h00m00s.

11.3 UT1

This is effectively mean solar time and is non-uniform as its rate matches the earth's varying rate of rotation. UT1 is needed to compute sidereal time, necessary for pointing a telescope. As UT1 is only determined by observation, its values are extrapolated to provide the value for a given day. The difference DUT1 = UT1 - UTC varies by 1-2 milliseconds per day.

11.4 GPS Time

The GPS satellites supply time on a uniform timescale that is a count of SI seconds since the GPS epoch, January 6, 1980. The difference from UTC was defined to be zero at the GPS epoch. The UTC - GPS offset increases at each leap second and reached 10 seconds as of January 1, 1995.

12.0 Gemini Clocks

There are a variety of clocks available to users of the Gemini systems: this is a summary of what they are and when they are used.

12.1 Bancomm Time using GPS

This is the most accurate time available on the Gemini systems and should be used whenever high accuracy is needed. The time information is obtained via a GPS receiver on the Master IOC using a Bancomm bc637 VME card, converted to the TAI timescale, and distributed to the bc635 card in the slave IOCs via a dedicated Time Bus using the IRIG-B time format.

The time can be read from this source in software using the EPICS and VxWorks interfaces described in this document.

12.2 Bancomm Real Time Clock (RTC)

Each Bancomm card has an on-board, battery-backed, real-time clock. This is available as a time-source for use with the Time Bus as a lower accuracy alternative to the GPS signal. As the time on this clock may drift considerably it should be re-initialized periodically to ensure that the time is reasonably accurate.

The RTC will only normally be used in the event of a persistent GPS failure: when the RTC is selected as the time source for the Bancomm the time values are read in the usual way via EPICS and VxWorks interfaces.

12.3 CPU board Real Time Clock

The CPU board in the IOC may have an on-board real-time clock: this is the case for the SIC default MVME167 processor board. This clock is separate and quite independent of the real-time clock on the Bancomm VME card. It can be set and interrogated using standard VxWorks procedures but should not normally be used in Gemini applications. There is no EPICS interface to this clock.

For further details see the VxWorks Reference Manual, procedures **clock_gettime()**, **clock_settime()** and **time()**. The time supplied by this clock should not be assumed to be valid.

12.4 VxWorks System Clock and Auxiliary System Clock

The MVME167 CPU board includes two Tick Timer chips, one of which is used by default by VxWorks to drive the system clock at a rate of 60Hz. These system clock tick interrupts can be used for timing intervals and scheduling purposes. This clock does not provide a time of day value. The other Tick Timer chip can be used to drive an auxiliary system clock which can provide interrupts independently of the system clock.

Gemini SIC systems do not use these timer chips if a Bancomm board is present as the system clock is driven at a precise rate using Bancomm periodic interrupts. This frequency is configurable and defined by a call to BcConfigure().

For details of VxWorks procedures which use these clocks see the Board Support Package routines **sysClk**<xxx> and **sysAuxClk**<xxx> for the appropriate CPU board**.**

12.5 EPICS Timestamp Soft Time

The timestamp value written with each EPICS record when it is processed is normally read directly from the Bancomm. The EPICS timestamp software also maintains a 'soft time' which is incremented in the timestamp driver software by counting each system clock tick. The time is maintained by the 'soft time master' IOC and synchronized to slave IOCs. It is used automatically by the EPICS timestamp software when Bancomm time is unavailable

12.6 Unix Workstations: NTP time

Gemini workstations running Unix will normally have their local clock time initialized and maintained using the Network Time Protocol (NTP). Absolute time returned from this clock can be assumed to be accurate to within a few milliseconds.