I/O Boards

Most I/O boards, are single width VME boards, of similar design and front cabinet, using the same digital signal processor (TMS320C32).

The central processing unit (CPU) is a high-speed processor designed for digital filtering and for working with data in IEEE 32-bit floating point format. The task scheduler operates at a 1 ms and 5 ms rate to support high-speed analog and discrete inputs. The I/O boards synchronize their input scan to complete a cycle before being read by the VCMI board. Contact inputs in the VCCC and VCRC are time stamped to 1 ms to provide a sequence of events (SOE) monitor.

Each I/O board contains the required sensor characteristic library, for example thermocouple and RTD linearizations. Bad sensor data and alarm signal levels, both high and low, are detected and alarmed. The I/O configuration in the toolbox can be downloaded over the network to change the program online. This means that I/O boards can accept tune-up commands and data while running.

Certain I/O boards, such as the servo and turbine board, contain special control functions in firmware. This allows loops, such as the valve position control, to run locally instead of in the controller. Using the I/O boards in this way provides fast response for a number of time critical functions. Servo loops, can be performed in the servo board at 200 times per second.

Each I/O board sends an identification message (ID packet) to the VCMI when requested. The packet contains the hardware catalog number of the I/O board, the hardware revision, the board barcode serial number, the firmware catalog number, and the firmware version. Also each I/O board identifies the connected terminal boards via the ID wire in the 37-pin cable. This allows each connector on each terminal board to have a separate identity.

I/O Processor Board	Terminal Board	I/O Signal Types	No. per I/O Processor Board	Type of Terminal Board	Comments
VAIC	TBAI (2)	Analog inputs, 0–1mA, 4–20 mA, voltage	20	TMR, simplex	
			4		
		Analog outputs, 4–20 mA, 0–200 mA			
VAOC	TBAO	Analog outputs, 4–20 mA	16	TMR, simplex	
VCCC and VCRC	TBCI (2)	Contact inputs	48	TMR, simplex	(VCCC is two slots)
	TRLY (2)	Relay Outputs (note 1)*	24	TMR, simplex	
VCCC	TICI (2)	Point Isolated Contact inputs	48	TMR, simplex	VCCC-only in place of TBCI. (optional)
VGEN	TGEN	Analog inputs, 4–20 mA	4	TMR, simplex	
		Potential transformers	2		
		Current transformers	3		
	TRLY	Relay outputs (optional)	12		for FAS (PLU)
VPRO (3)	TPRO	Pulse rate	3	TMR	Emergency Protect
		Potential transformers	2		
		Thermocouples	3		
		Analog inputs, 4–20 mA	3		

Vibration

Seismic

Universal Building Code (UBC) - Seismic Code section 2312 Zone 4

Operating / Installed at Site

Vibration of 1.0 G Horizontal, 0.5 G Vertical at 15 to 120 Hz

See Seismic UBC for frequencies lower than 15 Hz.

Packaging

The standard Mark VI cabinets meet NEMA 1 requirements (similar to the IP-20 cabinet). Optional cabinets for special applications meet NEMA 12 (IP-54), NEMA 4 (IP-65), and NEMA 4X (IP-68) requirements. Redundant heat exchangers or air conditioners, when required, can be supplied for the above optional cabinets.

UL Class 1 Division 2 Listed Boards

Certain boards used in the Mark VI are UL listed (E207685) for Class 1 Division 2, Groups A, B, C, and D, Hazardous Locations, Temperature Class T4 using UL-1604.

Division 2 is described by NFPA 70 NEC 1999 Article 500 (NFPA - National Fire Protection Assocation, NEC - National Electrical Code).

The Mark VI boards/board combinations that are listed may be found under file number E207685 at the UL website and currently include:

- IS200VCMIH1B, H2B
- IS200DTCCH1A, IS200VTCCH1C
- IS200DRTDH1A, IS200VRTDH1C
- IS200DTAIH1A, IS200VAICH1C
- IS200DTAOH1A, IS200VAOCH1B
- IS200DTCIH1A, IS200VCRCH1B
- IS200DRLYH1B
- IS200DTURH1A, IS200VTURH1B
- IS200DTRTH1A
- IS200DSVOH2B, IS200VSVOH1B
- IS200DVIBH1B, IS200VVIBH1C
- IS200DSCBH1A, IS200VSCAH2A
- IS215UCVEH2A, M01A, M03A, M04A, M05A
- IS215UCVDH2A
- IS2020LVPSG1A

Algorithm Descriptions

This section describes the synchronizing algorithms in the VTUR I/O processor, and then VPRO.

Automatic Synchronization Control in VTUR (K25)

VTUR runs the auto synch algorithm. Its basic function is to monitor two Potential Transformer (PT) inputs, generator and bus, to calculate phase and slip difference, and when armed (enabled) from the application code, and when the calculations anticipate *top center*, to attempt a breaker closure by energizing relay K25. The algorithm uses the *zero voltage crossing* technique to calculate phase, slip, and acceleration. It compensates for breaker closure time delay (configurable), with self-adaptive control when enabled, with configurable limits. It is interrupt driven and must have generator voltage to function. The configuration can manage the timing on two separate breakers. For details, refer to the figure below.

The algorithm has a bypass function, two signals for redundancy, to provide dead bus and Manual Breaker Closures. It anticipates top dead center, therefore it uses a projected window, based on current phase, slip, acceleration, and breaker closure time. To pickup K25, the generator must be currently lagging, have been lagging for the last 10 consecutive cycles, and projected (anticipated) to be leading when the breaker actually reaches closure. Auto synch will not allow the breaker to close with negative slip. In this fashion, assuming the correct breaker closure time has been acquired, and the synch check relay is not interfering, breaker closures with less than 1 degree error can be obtained.

Slip is the difference frequency (Hz), positive when the generator is faster than the bus. Positive phase means the generator is leading the bus, the generator is ahead in time, or the right hand side on the synchroscope. The standard window is fixed and is not configurable. However, a special window has been provided for synchronous condenser applications where a more permissive window is needed. It is selectable with a signal space Boolean and has a configurable slip parameter.

The algorithm validates both PT inputs with a requirement of 50% nominal amplitude or greater; that is, they must exceed approximately 60 V rms before they are accepted as legitimate signals. This is to guard against cross talk under open circuit conditions. The monitor mode is used to verify that the performance of the system is correct, and to block the actual closure of the K25 relay contacts; it is used as a confidence builder. The signal space Input Gen_Sync_Lo will become true if the K25 contacts are closed when they should not be closed, or if the Synch Check K25A is not picked up before the Auto Synch K25. It is latched and can be reset with Synch_Reset.

The algorithm compensates for breaker closure time delay, with a nominal breaker close time, provided in the configuration in milliseconds. This compensation is adjusted with self-adaptive control, based upon the measured breaker close time. The adjustment is made in increments of one cycle (16.6/20 ms) per breaker closure and is limited in authority to a configurable parameter. If the adjustment reaches the limit, a diagnostic alarm *Breaker #n Slower/Faster Than Limits Allows* is posted.

Configuration

VTUR configuration of the auto synch function is shown the following table. The configuration is located under J3 J5: IS200VTUR, signal Ckt_Bkr.

TUR Auto Synch Configuration

VTUR Parameter	Description	Selection Choice
SystemFreq	System Frequency	50 Hz, 60 Hz
CB1CloseTime	Breaker #1 closing time	0 to 500 ms
CB1AdaptLimt	Breaker #1 adaption limit	0 to 500 ms
CB1AdaptEnabl	Breaker #1 adaption enable	Enable, disable
CB1FreqDiff	Breaker #1 allowable frequency difference for the special window	0.15 to 0.66 Hz
CB1PhaseDiff	Breaker #1 allowable phase difference for the special window	0 to 20 degrees
CB2CloseTime	Breaker #2 closing time	0 to 500 ms
CB2AdaptLimt	Breaker #2 adaption limit	0 to 500 ms
CB2AdaptEnabl	Breaker #2 adaption enable	Enable, disable
CB2FreqDiff	Breaker #2 allowable frequency difference for the special window	0.15 to 0.66 Hz
CB2PhaseDiff	Breaker #2 allowable phase difference for the special window	0 to 20 degrees

VPRO configuration of the Synch Check Function is shown in the following table. The configuration is located under J3: IS200TREX, signal K25A_Fdbk.

VTUR Auto Synch Configuration

VPRO Parameter	Description	Selection Choice
SynchCheck	Enable	Used, unused
SystemFreq	System Frequency	50 Hz, 60 Hz
ReferFreq	Phase Lock Loop center frequency	PR_Std, SgSpace Where PR_Std means use PulseRate1 on a single shaft application - use PulseRate2 on all multiple shaft applications SgSpace means use generator freq (Hz), from signal space (application code), DriveFreq
TurbRPM	Load Turbine rated RPM	0 to 20,000 Used to compensate for driving gear ratio between the turbine and the generator
VoltageDiff	Allowable voltage difference	1 to 1,000 Engineering units, kV or percent
FreqDiff	Allowable freq difference	0 to 0.5 Hz
PhaseDiff	Allowable phase difference	0 to 30 degrees
GenVoltage	Allowable minimum gen voltage	1 to 1,000 Engineering units, kV or percent
BusVoltage	Allowable minimum bus voltage	1 to 1,000 Engineering units, kV or percent

This section defines all inputs and outputs in signal space that are available to the application code for synchronization control. The breaker closure is not given directly from the application code, rather the synchronizing algorithms, located in the I/O boards, is armed from this code. In special situations the synch relays are operated directly from the application code, for example when there is a dead bus.

The VTUR signal space interface for the Auto Synch function is shown in the following table.

VTUR Auto Synch Signal Space Interface

VTUR Signal Space Output	**Description**	**Comments**
Sync_Perm_AS	Auto Synch permissive	Traditionally known as L83AS
Sync_Perm	Synch permissive mode, L25P	Traditionally known as L25P; interface to control the K25P relay
Sync_Monitor	Auto Synch monitor mode	Traditionally known as L83S_MTR; enables the Auto Synch function, except it blocks the K25 relays from picking up
Sync_Bypass1	Auto Synch bypass	Traditionally known as L25_BYPASS; to pickup L25 for Dead Bus or Manual Synch
Sync_Bypass0	Auto Synch bypass	Traditionally known as L25_BYPASSZ; to pickup L25 for Dead Bus or Manual Synch
CB2 Selected	#2 Breaker is selected	Traditionally known as L43SAUTO2; to use the breaker close time associated with Breaker #2
AS_WIN_SEL	Special Auto Synch window	New function, used on synchronous condenser applications to give a more permissive window
Synch_Reset	Auto Synch reset	Traditionally known as L86MR_TCEA; to reset the synch Lockout function
VTUR Signal Space Inputs		
Ckt_BKR	Breaker State (feedback)	Traditionally known as L52B_SEL
CB_Volts_OK	Breaker Closing Coil Voltage is present	Used in diagnostics
CB_K25P_PU	Breaker Closing Coil Voltage is present downstream of the K25P relay contacts	Used in diagnostics
CB_K25_PU	Breaker Closing Coil Voltage is present downstream of the K25 relay contacts	Used in diagnostics
CB_K25A_PU	Breaker Closing Coil Voltage is present downstream of the K25A relay contacts	Used in diagnostics
Gen_Sync_LO	Synch Lock out	Traditionally known as L30AS1 or L30AS2; it is a latched signal requiring a reset to clear (Synch_Reset). It detects a K25 relay problem (picked up when it should be dropped out) or a slow Synch Check (relay K25A) function

VTUR Diagnostics for the Auto Synch Function

L3BKR_GXS – Synch Check Relay is Slow. This means that K25 (auto synch) has picked up, but K25A (synch check) or K25P has not picked up, or there is no breaker closing voltage source. If it is due to a slow K25A relay, the breaker will close but the K25A is interfering with the K25 optimization. It will cause the input signal Gen_Sync_LO to become TRUE.

L3BKR_GES – Auto Synch Relay is Slow. This means the K25 (auto synch) relay has not picked up when it should have, or the K25P is not picked up, or there is no breaker closing voltage source. It will cause the input signal Gen_Sync_LO to become TRUE.

Breaker #1 Slower than Adjustment Limit Allows. This means, on breaker #1, the self-adaptive function adjustment of the Breaker Close Time has reached the allowable limit and can not make further adjustments to correct the Breaker Close Time.

Breaker #2 Slower than Adjustment Limit Allows. This means, on breaker #2, the self-adaptive function adjustment of the Breaker Close Time has reached the allowable limit and can not make further adjustments to correct the Breaker Close Time.

Synchronization Trouble – K25 Relay Locked Up. This means the K25 relay is picked up when it should not be. It will cause the input signal Gen_Sync_LO to become TRUE.

VPRO Diagnostics for the Auto Synch Function

K25A Relay (synch check) Driver mismatch requested state. This means VPRO cannot establish a current path from VPRO to the TREx terminal board.

K25A Relay (synch check) Coil trouble, cabling to P28V on TTUR. This means the K25A relay is not functional; it could be due to an open circuit between the TREx and the TTUR terminal boards or to a missing P28 V source on the TTUR terminal board.

Hardware Verification Procedure

The hardware interface may be verified by forcing the three synchronizing relays, individually or in combination. If the breaker close coil is connected to the TTUR terminal board, then the breaker must be disabled so as not to actually connect the generator to the system bus.

1 Operate the K25P relay by forcing output signal Sync_Perm found under VTUR, card points. Verify that the K25P relay is functional by probing TTUR screws 3 and 4. The application code has direct control of this relay.

2 Simulate generator voltage on TTUR screws 17 and 18. Operate the K25 relay by forcing TTUR, card point output signals Sync_Bypass1 =1, and Sync_Bypass0 = 0. Verify that the K25 relay is functional by probing screws 4 and 5 on TTUR.

3 Simulate generator voltage on TPRO screws 1 and 2. Operate the K25A relay by forcing TPRO, card point output signals SynCK_Bypass =1, and SynCk_Perm 1. The bus voltage must be zero (dead bus) for this test to be functional. Verify that the K25A relay is functional by probing screws 5 and 6 on TTUR.

Synchronization Simulation

➢ **To simulate a synchronization**

1 Disable the breaker

2 Establish the center frequency of the VPRO PLL; this depends on the VPRO configuration, under J3:IS200TREx, signal K25A_Fdbk, **ReferFreq**.

a. If ReferFreq is configured PR_Std, and <P> is configured for a single shaft machine, then apply rated speed (frequency) to input **PulseRate1**; that is TPRO screw pairs 31/32, 37/38, and 43/44.

b. If ReferFreq is configured PR_Std and <P> is configured for a multiple shaft machine, then apply rated speed (frequency) to input **PulseRate 2**, that is TPRO screw pairs 33/34, 39/40, and 45/46.

c. If ReferFreq is configured SgSpace, force VPRO signal space output **DriveRef** to 50 or 60 (Hz), depending on the system frequency.

3 Apply the bus voltage, a nominal 115 V ac, 50/60 Hz, to TTUR screws 19 and 20, and to TPRO screws 3 and 4.

4 Apply the generator voltage, a nominal 115 V ac, adjustable frequency, to TTUR screws 17 and 18 and to TPRO screws 1 and 2. Adjust the frequency to a value to give a positive slip, that is VTUR signal GenFreqDiff of 0.1 to 0.2 Hz. (10 to 5 sec scope).

5 Force the following signals to the TRUE state:

- VTUR, **Sync_Perm**, then K25P should pick up
- VTUR, **Sync_Perm_AS**, then K25 should pulse when the voltages are in phase
- VPRO, **SynCK_Perm**, then K25A should pulse when the voltages are in phase

6 Verify that the TTUR breaker close interface circuit, screws 3 to 7, is being made (contacts closed) when the voltages are in phase.

7. Run a trend chart on the following signals:
   - VPRO: GenFreqDiff, GenPhaseDiff, L25A_Command, K25A_Fdbk
   - VTUR: GenFreqDiff, GenPhaseDiff, L25_Command, CB_K25_PU, CB_K25A_PU
8. Use an oscilloscope, voltmeter, synchroscope, or a light to verify that the relays are pulsing at approximately the correct time.
9. Examine the trend chart and verify that the correlation between the phase and the close commands is correct.
10. Increase the slip frequency to 0.5 Hz and verify that K25 and K25A stop pulsing and are open.
11. Return the slip frequency to 0.1 to 0.2 Hz, and verify that K25 and K25A are pulsing. Reduce the generator voltage to 40 V ac and verify that K25 and K25A stop pulsing and are open.

Fast Overspeed Trip in VTUR

In special cases where a faster overspeed trip system is required, the VTUR Fast Overspeed Trip algorithms may be enabled. The system employs a speed measurement algorithm using a calculation for a predetermined tooth wheel. Two overspeed algorithms are available in VTUR as follows:

- PR_Single. This uses two redundant VTUR boards by splitting up the two redundant PR transducers, one to each board.
- PR_Max. This uses one VTUR board connected to the two redundant PR transducers. PR_Max allows broken shaft and deceleration protection without the risk of a nuisance trip if one transducer is lost.

The fast trips are linked to the output trip relays with an OR-gate as shown in the following figures. VTUR computes the overspeed trip, not the controller, so the trip is very fast. The time from the overspeed input to the completed relay dropout is 30 msec or less.