Built-In diagnostics

The MFT B-series has an extensive set of internal and external sensor/wiring checks it performs and reports. The following diagnostic tools are provided to support service techs and minimize the amount of down-time on the meter. Intermittent events will also be captured for further evaluation allowing for faster corrective action. Some of the tools are designed for use with the LCD/keypad, some via Tera Term (open source Terminal Emulator for the PC) or KzComm (Kurz upload/download program) and some via Modbus. The available tools are:

- Bit-mapped multiple error readouts in hexadecimal and ASCII text for the operator
- Internal event logs, 200 FIFO records of the above error code and meter run-time.
- Min/Max event memory captures the daily extremes for velocity, flow rate, temperature, electronics temperature and the run time this occurred at. This memory has 20 records for each of the above variables.
- Trend data record of 20,416 records captured every 10 seconds. This permits 56+ hours of volatile memory of the flow rate, temperature and run-time, provided the meter does not loose power.
- The current error codes or meter status can be read via the Modbus registers. (see Modbus section for details)
- NE-43 alarm, below 3.6 mA or above 21 mA which maps many of the bit mapped errors to NE-43 alarms. (see Figure E-1 for mapping of errors to alarms)
- Diagnostic data available with the tech access code. This is provided to aid troubleshooting with extra variable type information beyond the yes/no statements of the error codes. There are 5 categories, many with sub menus listed below:
    - Input voltages
    - Sensor leakage
    - Electronics Temperature
    - Sensor Control
    - Sensor Output

Figure E-1 Lower Word Error Code bit mapping.

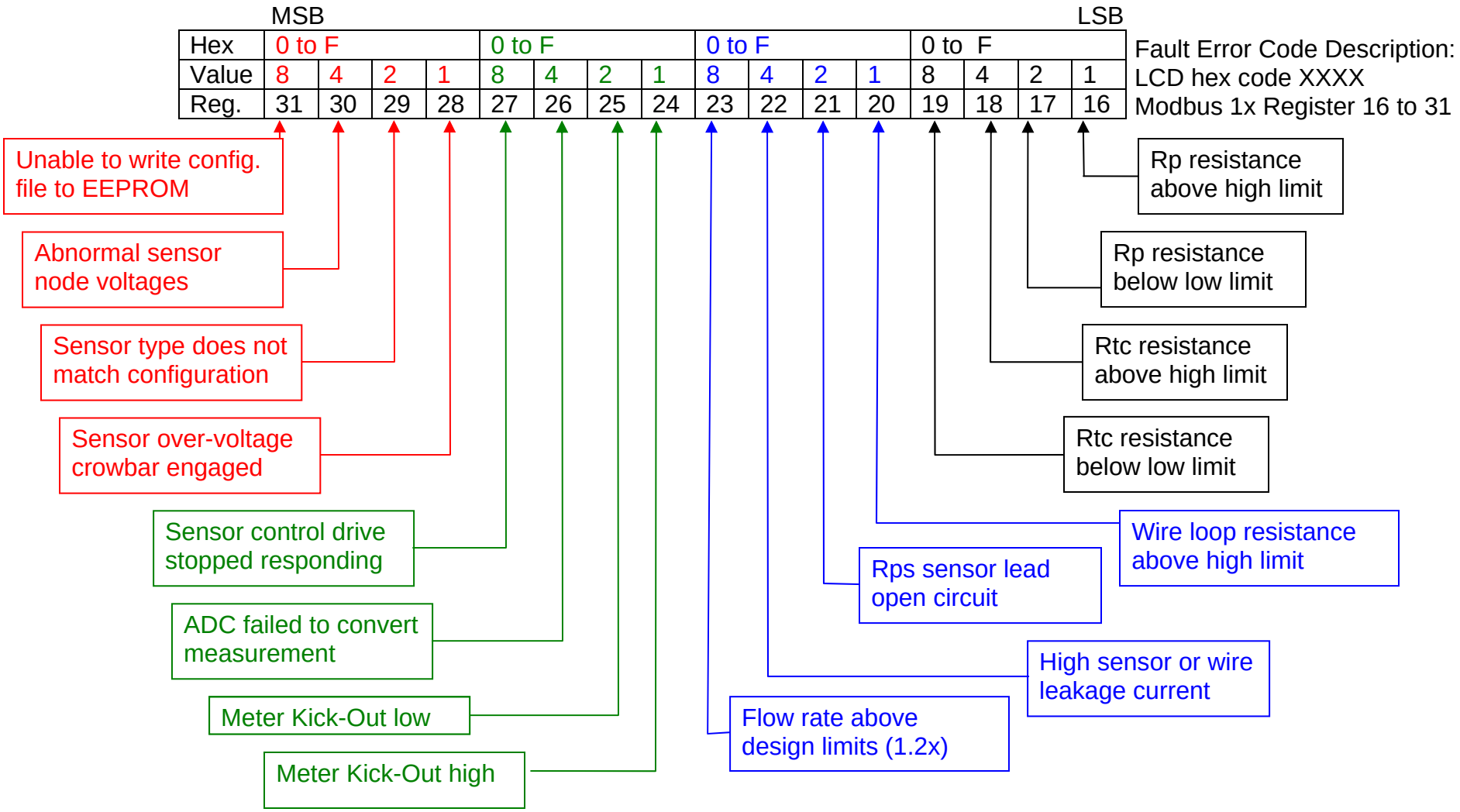


Figure E-2 Upper Word Error Code bit mapping.

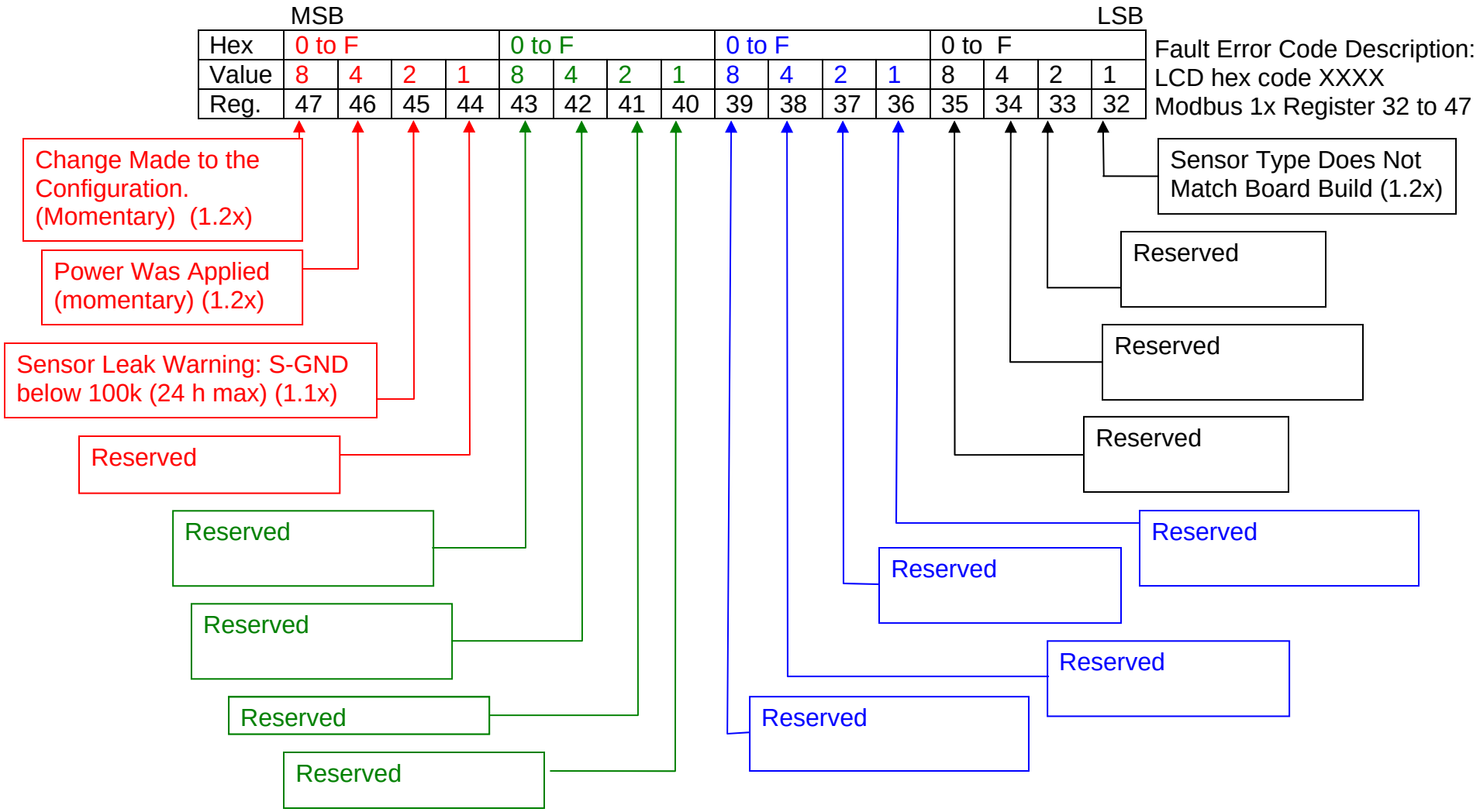


Table E-1. MFT B-Series Diagnostic Error limits

Parameter	Low Limit	High Limit	Comments
Vps	0.150 V	17.6 V	Sensor drive voltage. (used for code 4xxx)
Vll	0.009 V	2.30 V	Sensor wire voltage (used for code 4xxx)
Viph	0.004 V	0.765 V	Sensor current sense voltage (used for code 4xxx)
Vrtch	0.4136 V	2.55 V	Rtc high side voltage (used for code 4xxx)
Vrtcl	0.310	2.55 V	Rtc low side voltage (used for code 4xxx)
Rp, velocity sensor 9/27 FD2 9/300 FD 9/100 MD 20/20 CD	Ohms 5.0 5.0 5.0 10.0	Ohms 30.0 30.0 (32.0) 30.0 60.0	Rp sensor resistance, sensor and temperature dependent. 600 °C mode, 1.1x or higher firmware.
Rtc, process temperature sensor 9/27 FD2 9/300 FD 9/100 MD 20/20 CD	Ohms 14.0 150 50 9	Ohms 100.0 1000.0 350.0 50.0	Rtc sensor resistance, Sensor and temperature dependent
Rwire	0.020 Ohms	5.00 Ohms	Sensor wire loop resistance (total)
Rleak	100 kOhms 20 kOhms		Sensor/wire leakage to ground for first 24 h in 600 °C mode
Rtc/Rp ratio	-10%	+10 %	Sensor Rtc/Rp ratio. Used to know the sensor type “Sensor Type Does Not Match”

Table E-2. Fault Error Code Meaning. (leading zeros are not shown in error codes)

Message/code	Meaning
Rp resistance above high limit Code: xxxxxxx1	Velocity sensor resistance is above the normal range for the sensor type configured. This accounts for sensor core temperature up to ~650 °C before setting the error. ~720 °C in 600 °C mode. Open circuit on the sensor wiring Defective sensor or SC electronics board

Rp resistance below low limit Code: xxxxxxx2	Velocity sensor resistance is below the normal range for the sensor type configured. This accounts for sensor down to -112 °C before setting the error. Short in the sensor wiring Defective sensor or SC electronics board
Rtc resistance above high limit Code: xxxxxxx4	The process temperature sensor resistance is above the normal range for the sensor type configured. This accounts for sensors up to 650 °C for the metal sensors, FD, FD2 and MD and 460 °C on the CD sensor Open circuit on the sensor wiring. Defective sensor or SC electronics board When this limit is reached, the meter will turn the drive off until it cools. This can cause the sensor to regulate at this temperature and set multiple errors in the log as it goes below and above the limit.
Rtc resistance below low limit Code: xxxxxxx8	The process temperature sensor resistance is below the normal range for the sensor type configured. This accounts for sensor down to -120 °C in normal operation before setting an error Short circuit on the sensor wiring. Defective sensor or SC electronics board.
Wire loop resistance above high limit Code: xxxxxx1x	The sensor wire resistance from the sensor it its electronics board is too high, > 5.0 ohms. Loop resistance is from the electronics out to a sensor and back. Wire is too long for the gage being used Loose wire joint connection (but not too loose, see code 20) Defective sensor or SC electronics board
Sensor Rps lead open circuit Code: xxxxxx2x	The sensor wire Rps is open circuit or not connected. Open circuit on the Rps wire, pin 1 of TB1. Open on the Rp lead will also set this, Pin 3, TB1 Defective Sensor or SC electronics board
High Sensor or wire leakage Code: xxxxxx4x	The sensor or wiring is showing too much leakage current to ground. The trip point of this error is the equivalent of 100 kOhms leakage resistance[1]. Wet or contaminated wiring or a junction box Water in the backend of a sensor Corroded front sided to a sensor

[1] Firmware version newer than 1.09 have a factory configuration option to allow operation up to 600 °C for the FD2 Sensor and the error code may be preceded by the warning code 2xxxxxxx.

	Sensor above temperature limit Defected SC electronics board At normal temperatures, three 10 minute leakage updates are required before the error is set.
Flow Rate Above Design Limits (1.2x firmware) Code xxxxxx8x	Under high heat flow conditions (very high flow rates), the demand to heat the sensor may exceed the drive limits of the SC electronics board. The reported flow readings at this point will be compressed and lower than the true flow readings.
Meter Kick-Out High Code: xxxxx1xx	If the flow rate or temperature is above the high kick-out limit in the meter, it will set this error code. This is a normal alarm if the flow rate or temperature is above the kick-out set point which is user programmable. Condensate on the velocity sensor can cause high heat flow and will set this also. A change in gas composition to high heat flow gases like H2 can cause this alarm.
Meter Kick-Out Low Code: xxxxx2xx	If the flow rate or temperature is below the low kick-out limit in the meter, it will set this error code. This is a normal alarm if the flow rate or temperature is below the kick-out set point which is user programmable. Drop in process pressure at very low flow rates can cause a loss in heat flow and will set this alarm. A change in gas composition to low heat flow gases like Ar can cause this alarm, or from CH4 to Air.
ADC failed to convert measurement Code: xxxxx4xx	The circuits on the SC board which measures the input signals are not working properly. The SC board is defected and needs to be replaced.
Sensor Control Drive stopped responding Code: xxxxx8xx	The sensor drive voltage to heat the velocity sensor is not matching the set point. Short or miss-wring of the sensor. The SC board is defective and needs replacement.
Sensor Over voltage crowbar engaged Code: xxxx1xxx	The sensor drive voltage was not matching the set point and would not fall to low drive on command. The crowbar SCR was engaged to clamp the sensor drive voltage to zero. Sensor field wiring short to a DC power supply

	(4-20 mA) or 24 V supply Defective SC board which needs replacement.
Sensor type does not match configuration Code: xxxx2xxx	The sensor resistance ratio, Rtc/Rp exceeds 10% of the normal value for the sensor the meter was configured for. Wrong sensor is connected to the electronics. Double check the SN matching Upset to the process temperature causing the two sensors (Rp and Rtc) to not match in temperatures Defective sensor or SC board.
Abnormal Sensor node voltages Code: xxxx4xxx	This fault is often a redundant error to the above entries on sensor and wiring faults. It is looking at the sensor wire voltages only, not just the resistance values. Miss-wired sensor. Short or Open circuit. Defective sensor or SC board.
Unable to write config. File to EEPROM Code: xxxx8xxx	The sensor and meter configuration data can not be verified after a memory write. Defective sensor control (SC) board Any EEPROM read/write fault may set this.
Sensor Type Does Not Match Board Build. (1.2x firmware) Code: xxx1xxxx	The version of the SC board hardware is not compatible with the connected sensor type. Board mix-up in production or field service Sensor failure, Board Failure
Code: xxx2xxxx	Reserved
Code: xxx4xxxx	Reserved
Code xxx8xxxx	Reserved
Code xx1xxxxx	Reserved
Code xx2xxxxx	Reserved
Code xx4xxxxx	Reserved
Code xx8xxxxx	Reserved
Code x1xxxxxx	Reserved
Code x2xxxxxx	Reserved
Code x4xxxxxx	Reserved
Code x8xxxxxx	Reserved
Code 1xxxxxxx	Reserved
Code 2xxxxxxx (1.1x firmware)	The sensor is in a process above 100 °C and is leaking current. It has 24 hours to recover to a leakage resistance above 100 k ohms before the warning is converted to an error. Note that if the leakage resistance is below 20 k or the process temperature is below 100 °C, it will automatically

	convert to an error without delay.[2] During the warning the meter will continue to output readings, but upon converting to an error the NE-43 alarms will be set and the meter will no longer output readings. This is designed to allow the sensor to operate while drying out its MI cable. Wet or contaminated wiring or a junction box Water in the backend of a sensor Corroded front sided to a sensor Sensor above temperature limit Defected SC electronics board
Power On or power Cycle (1.2x firmware) Code: 4xxxxxxx	This is a momentary code which occurs every time the unit boots up or there is a power cycle. It is logged in the event logs for diagnostics purposes.
Configuration Change (1.2x firmware) Code: 8xxxxxxx	This is a momentary code which is logged in the event log any time the meter programming or configuration has been changed. This is for diagnostics purposes. If other errors or meter trouble started after a configuration change, this will support identifying this issue. The type of change is not recorded, only that a change was made and the meter's run time for the change.

Example error codes:

```
Fault Err Event
Code: 200
```

This means starting with the right or LSB, we have a hex code of 0x0200, the leading zero is not shown. There is a single error or bit set, "Meter Kick-out low". This means the flow reading was too low or below the lower limit of the Kick-out low which is a user defined flow or velocity point set in Program Mode.

When multiple errors are detected at the same time, the codes get more complicated. For example if you disconnect the sensor wires after the meter has booted up you will read:

[2] Firmware version newer than 1.09 have a factory configuration option to allow operation up to 600 °C for the FD2 Sensor and the warning code may be followed by the error xxxxxx4x.

```
Fault Err Event
Code: 4025
```

This can be decoded using the following bit logic (from big table shown previously)

Table E-3 Decoding Error Codes, Two examples shown 4025 and 0200.

Digit value	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1
Modbus Register #	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Error code	4				0				2				5			
Set Error Register #	30				none				21				18 and 16			
Error code	0				2				0				0			
Set Error Register #	none				25				none				none			

Error code 0x4025. The upper 4 means Abnormal Sensor Node Voltage (register 30), the zero means no errors in the registers 27 to 24, the 2 means the velocity sensor wire resistance sense lead (Rps) is open circuit (register 21 set), the 5 means the hex 4 and hex 1 are both set or Rtc resistance too high (register 18 set) and Rp resistance too high (register 16 set). So instead of multiple errors being reported as separate codes, all known errors are reported in the code at the same time. In this example the sensor control board is telling you there is no sensor connected since the voltages are abnormal, Rps lead is open circuit, Rp and Rtc are reading high impedance. The error register numbers are for the 1xxxx Modbus registers.

Table E-4. Some single wire fault error codes and results. AC powered version of 454FTB.

Fault Code	Fault
0000	None
20	Rps open circuit
4000	Rp short to GND
4000	Rtcl short to GND
4004	Rtcl open circuit
4004	Rtch open circuit
4008	Rtch short to GND
401a	Rpl open circuit
4021	Rp open circuit
Shuts down, reboot attempt every 1 second.	24 V short to Rps. AC supply goes into current limit.
Shuts down, reboot attempt every 1 second	24 V short to Rpl. AC supply goes into current limit.
Shuts down, reboot attempt every 1 second	24 V short to Rp. AC supply goes into current limit.
Shuts down, reboot attempt every 1 second	24 V short to Rtcl permanent fault. Abnormal sensor node voltages. SC board must be serviced.
Shuts down, reboot attempt every 1 second	24 V short to Rtch, permanent fault. Abnormal sensor node voltages. SC board must be serviced.

Error Code and 24 hour Min/Max log.

To facilitate intermittent errors and troubleshooting, the flow meter records its most recent 200 error codes and corresponding elapsed run-time. Associated with this is a 24 h min/max record for the top or bottom 20 extremes of velocity, flow rate, process temperature, electronics temperature and the run time that these occurred.

The internal logs are accessed in two ways.

- In *Program Mode* under the Diagnostic menu you can transfer the data via terminal emulator like HyperTerminal through the USB interface to a PC.
- Using KzComm you can extract that data via Modbus on the RS-485 multipoint network interface or via the USB interface.

Accessing the logs using Tera Term

You load Tera Term from the Start menu and connect at 9600 baud to the COM port # the Kurz USB driver has enumerated on. You will see the meter scrolling through meter 1 and meter 2 data. If you want to capture this data it is best to save it as a .csv file so it can be imported to Excel easily.

To extract the data we do the following: Press **P** to enter *Program Mode* using the "654321" tech code followed by "enter". Then using the **v** or down key advanced to the menu:

```
PRESS E TO SEE
DIAGNOSTIC DATA
```

Press "enter" and the next menu will be:

```
SELECT ITEM  ^v
DIAGNOSTIC DATA
```

Now press **v** to advance to the menu:

```
SELECT ITEM  ^v
FAULT EVENT DATA
```

Now press "enter" for the next menu:

```
SELECT ITEM  ^v
SEE FAULT ERROR
```

Next press **v** key to see:

```
SELECT ITEM  ^v
DOWNLOAD RECORDS
```

Pressing "enter" will send all the logged errors and the 24 hour min/max events to the terminal program as shown in the following example, including the above menu sequence.

Example data captured using a Tera Term session from the moment the **P** key was pressed until the data was extracted looks like the following.

```
ENTER ACCESS  CODE:
ENTER ACCESS  CODE: *
ENTER ACCESS  CODE: **
ENTER ACCESS  CODE: ***
ENTER ACCESS  CODE: ****
ENTER ACCESS  CODE: *****
ENTER ACCESS  CODE: ******
```

PRESS E TO SET SYSTEM OF UNITS
PRESS E TO LOAD DATA FROM EEPROM
PRESS E TO SEE DIAGNOSTIC DATA
SELECT ITEM ^v DIAGNOSTIC DATA
SELECT ITEM ^v DIAGNOSTIC DATA
SELECT ITEM v DIAGNOSTIC DATA
SELECT ITEM ^v FAULT EVENT DATA
SELECT ITEM ^v SEE FAULT ERROR
SELECT ITEM ^v DOWNLOAD RECORDS

Sensor Serial Number:FD20293A
Board Serial Number:A77437
Current Runtime:574290 Seconds

FAULT EVENTS

Runtime (sec)	Error Code
303	100
11343	100
17702	100
18460	100
19501	100
23100	100
282615	200
379307	4000

MINIMUM FLOWRATE

Runtime	Flowrate	Process Temp.	Elec. Temp.
89998	3791.951	72.19	83.44
89998	2788.527	75.56	83.68
24898	2.9754	89.44	76.93
256884	1.4078	84.05	74.81
283203	0	96.83	83.83
379901	0	81.73	74.97
500403	0	82.76	79.21

MAXIMUM FLOWRATE

Runtime	Flowrate	Process Temp.	Elec. Temp.
89998	4049.797	72.17	83.44
89998	2099.125	75.48	83.68
23098	15209.69	68.63	77.28
96416	44.6009	103.74	77.75
181158	25.2368	99.26	76.31
282606	10772.09	36.11	83.1
379304	10005.13	71.2	76.62
499806	15556.59	75.79	78.54

MINIMUM PROCESS TEMPERATURE

Runtime	Flowrate	Process	Elec. Temp.

		Temp.	
89998	4286.647	72.15	83.44
89998	1487.096	75.38	83.68
23696	283.2458	66.39	71.3
164931	4.3922	87.1	75.57
253879	1.8513	84.01	74.57
282606	10768.04	37.7	82.01
379304	5095.426	71.11	76.62
499807	13502.04	76	76.84

MAXIMUM PROCESS TEMPERATURE

Runtime	Flowrate	Process Temp.	Elec. Temp.
84998	25.6216	96.58	76.43
96416	44.6009	103.74	77.75
181158	25.2368	99.26	76.31
283804	0	105.78	85.89
406345	0	84.11	86.43
502206	0	85.72	85.37
89998	4437.403	72.14	83.44
89998	1092.001	75.22	83.68

MINIMUM ELECTRONICS TEMPERATURE

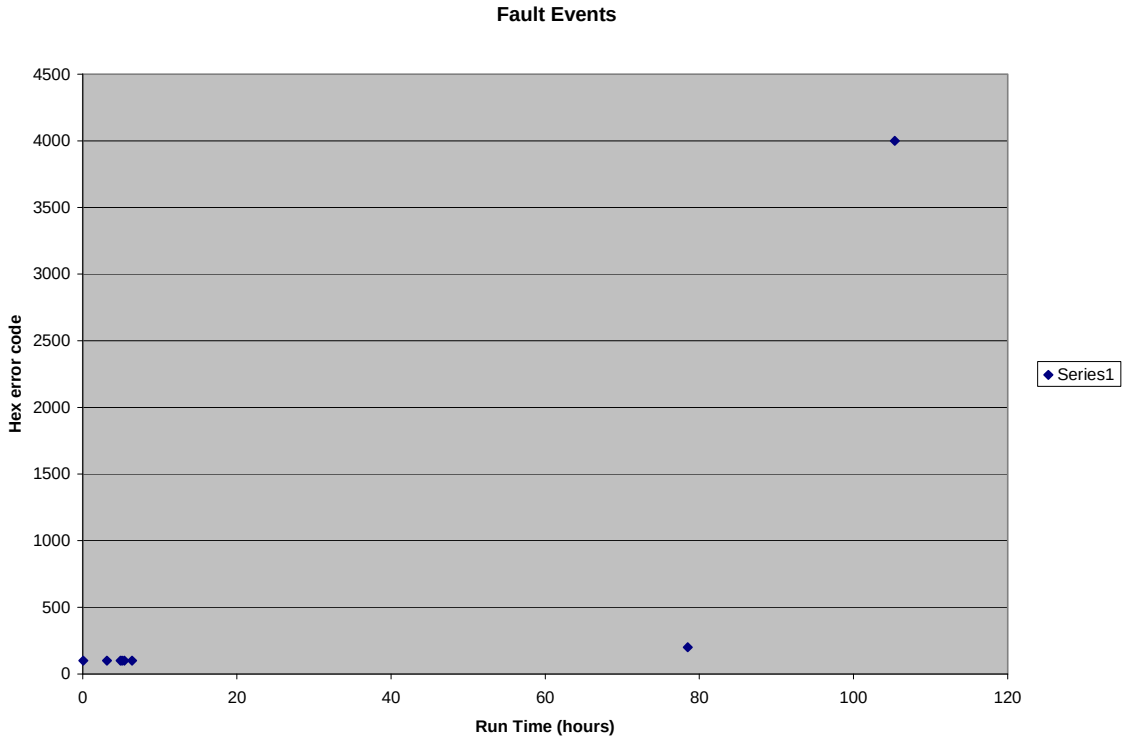
Runtime	Flowrate	Process Temp.	Elec. Temp.
23696	283.2458	66.39	71.3
167936	11.4915	93.33	73.54
252076	2.0109	84.88	74.38
282607	10526.49	41.38	81.11
379305	1646.715	71.21	74.48
499808	3799.746	76.18	75.44
89998	4575.884	72.13	83.44
89998	805.4492	74.99	83.68

MAXIMUM ELECTRONICS TEMPERATURE

Runtime	Flowrate	Process Temp.	Elec. Temp.
35716	5.1919	90.81	79.58
100023	5.0018	91.96	80.36
194380	5.0601	89.98	79.56
286809	0.5977	91.3	89.78
409951	0	82.95	86.67
506413	0	84.65	87.26
89998	4664.029	72.13	83.44
89999	604.6403	74.73	82.8

END OF RECORDS AT RUNTIME: 574296 SECONDS

All run times are saved in seconds. Plotting the fault events as an XY scatter plot in Excel we get, where the seconds have been converted to hours.



Which show the time distribution of the errors (only the first two significant bytes of the error code show up in this plot). This can be correlated with know events for the process or maintenance which was performed etc. This type of plot is easy to do and makes it much easier to understand the significance of the error codes.

For the Min/Max events, we note that each record entry has 4 items, Flowrate, Process Temp, Electronics Temp and Runtime. These entries are made on a daily (24h of runtime) basis. There are 6 logged categories, Min/Max Flowrate, Min/Max Process Temp and Min/Max Electronics Temp. Each category has 20 records. During the first 20 days of operation it will be tossing out the default record values (those whose runtime is 0 seconds) from the list. The order of the records 1 to 20 is not sorted. The lowest low flow or the highest high flow can be located in any of the record locations of that category. Plotting the min/max data using the X-Y scatter plot can also be helpful when trying to correlate process events with meter faults.

Using KzComm to extract the error event and min-max logs.

The error log and min-max log are saved as separate .csv files. As KzComm supports USB, Modbus serial and Modbus TCP/IP via a gateway, it is an integrated program to capture this diagnostic data. The format of these files is similar to what was shown above using the diagnostic menu and capturing data sent out the port but also includes the time in hours since the data transfer to a

PC, which is a relative time. See the KzComm manual for more on how this looks and works.

Volatile Trend Data memory.

Volatile memory (SRAM) in the flow meter will record 56+ hours of history provided there is no interruption in the power to the meter. This is another tool to isolate and understand intermittent process and flow meter issues. This data is accessed using the USB interface and Tera Term as are the error events or it is access using KzComm and the USB or Modbus interface.

There are a total of 20,416 records, 10 seconds apart and each record is three numbers: Flow Rate, Temperature and Run-time. The memory is written as a first-in, first-out buffer or FIFO. Both the run time in seconds and the time in hours counting back from the memory download are shown in the spread sheet. This is an example of a header:

TREND LOG

DATE:	11\14\2007
TIME:	13:05
Sensor Serial Number:	FD00000A
Meter 1 ID:	FLOW RATE
Current Runtime:	216994
NUMBER OF RECORDS:	1661

Runtime	Time From Download (hrs)	Flowrate (SCFM)	Temperature (DEGF)
215535	-0.40528	301.2267	82.89966
215525	-0.40806	309.7246	82.75954
215515	-0.41083	303.265	82.96161
215505	-0.41361	307.9795	83.51061
215495	-0.41639	307.9881	83.42668
215485	-0.41917	308.203	83.39914
215475	-0.42194	302.4459	83.4002
215465	-0.42472	314.0277	84.27499
215455	-0.4275	315.4738	84.42581
215445	-0.43028	316.9582	83.68893
215434	-0.43333	305.9884	83.32154
215425	-0.43583	317.662	83.74442
215415	-0.43861	309.0524	83.121

On a power cycle, all the data records are set to zero and the accumulation starts over. As this memory represents 245 kbytes of memory, it is too big and updated

too often to be stored in the EEPROM used for the meter configuration or error log.

The data transfer time using KzComm for a 56 hour trend log at 57,600 baud using Modbus serial can take about 4 minutes. Using the USB interface (lower baud rate) and the Xmodem protocol this is about 17 minutes.

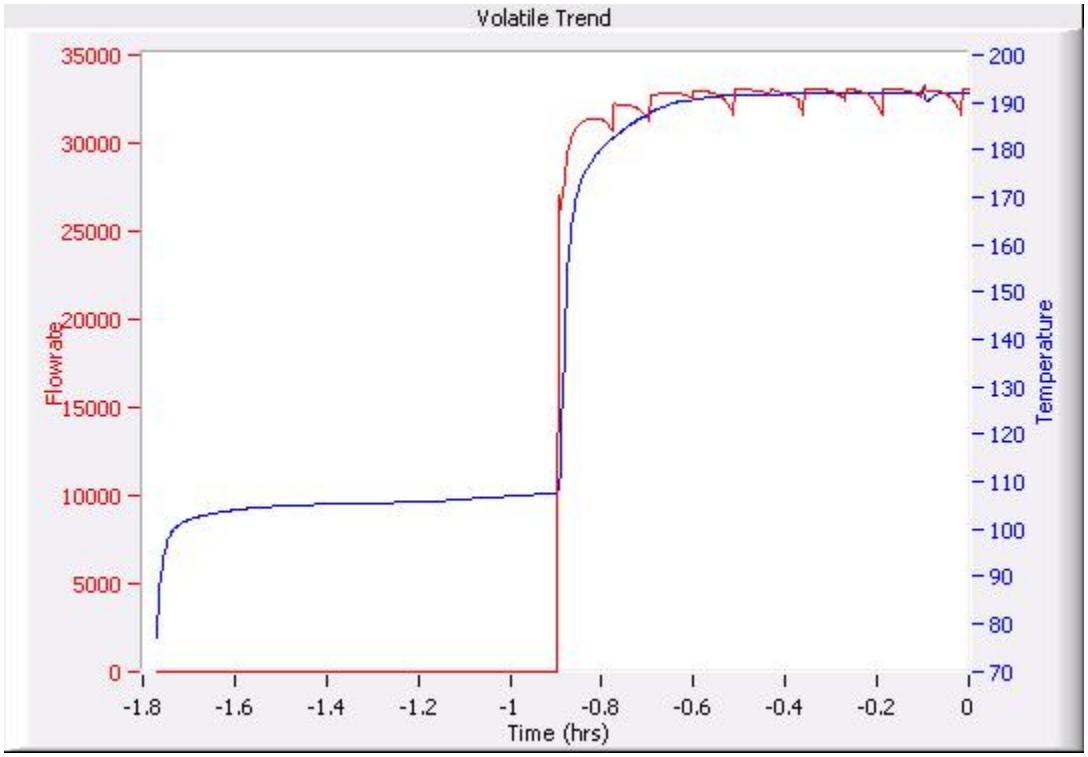


Figure E-2. Example trend data from volatile memory.

Internal Diagnostic Measurement Menus.

Advanced users and customers instructed by Kurz service personal can make use of the many analog parameters in the Diagnostic Data menus. Process or meter trouble may be more subtle than the yes/no errors from the error code so these “raw data” analog measurements are provided. These are broken down in the following categories.

- Input voltages
  - Voltages measured by the ADC from which all other parameters are computed.
- Sensor leakage
  - This is the common mode resistance from Rtch to Chassis ground. It is measured at boot up and every 10 minutes there after.
- Electronics Temperature

        - This is the sensor control (SC) board temperature sensor. This board will operate up to ~20 °C above the ambient of the meter environmental enclosure depending on the process flow rate. Higher flow rates will cause higher board temperatures.
    - Sensor Control
        - This are the PID control values of the velocity sensor.
    - Sensor Output
        - Velocity sensor current, power, resistance, temperature and the reference sensor resistance and temperature.

Specific menu screens and nomenclature can be found on the diagram 342042. The above menus are found in the *Program Mode* under the category “See Diagnostic Data” press **E** or enter then select “Diagnostic Data” using the **v** or **^** key and **P** or enter then chose the above categories using the **^** or **v** keys and **P** or enter. Us the **P** key to advance in the through the parameter screens.