The digital signal processor (DSP) in the Model 1133A Power Sentinel measures dozens of different parameters of the applied input signals, in many cases at a rate of 20 measurements per second. Most of these parameters may be used to trigger an alarm condition, based on preset conditions.

Triggering in the DSP works as follows. First, there are 32 different measurement types which may be selected for processing by the trigger algorithm. For each of these, there are (typically) four different measurement channels, A, C, B and either average, total, or maximum (of A, C, and B). Thus, there are a total of 128 different signals (corresponding to individual measurement results) which can be selected. Not all of these are defined at this time, however.

Second, there are 32 trigger channels which may be configured for use concurrently. Each of these may be set to use any of the 128 signals as their input. For each channel, there is a limit which may be set by the user, as well as a reference value which may be used by the trigger logic. The limit function logic may be set to any of four modes: x > limit; x < limit, |x| > limit; or |x – ref| > limit. In addition, each trigger channel may be made dependent on the results of another channel. It may be set so that the channel requires the other trigger to be either active or inactive before proceeding with its own comparison. Comparisons are made at the 20 per second rate for all channels, even for input signals which change more slowly.

Each channel also has a dwell time, or delay time, register. Before reporting an event, the specified signal must exceed its limit condition for a number of comparisons equal to this register (plus one). The register is a 16-bit unsigned integer, having a range of 0 to 65535 cycles. Since comparisons are performed 20 times per second, this corresponds to a range of dwell time of 0 to 3276.75 seconds. A value of 0 allows the trigger to be recognized at any time the corresponding condition is true; a value of 1 requires the trigger condition to persist for two consecutive comparisons, and so on.

Considering all of the different input signal possibilities, along with the different limit modes and inter-channel dependencies, there are an almost limitless number of possible combinations of settings for each trigger channel.

Detecting Oscillatory Transients and Other Anomalies

Special logic is included in the Model 1133A to implement the algorithms described by Schulz and Laios[1], which are designed to detect power system anomalies such as oscillatory transients. There are six channels dedicated to performing this function in the Model 1133A. Each of these may have any of the 128 signals described above as its input. Each channel has three outputs: a lowpass-filtered (‘bound’) output; a rate-of-change output; and an oscillation-detector output. Each channel also has three control parameters (in addition to the input signal selection): the rate-of-change filter time constant (T_1 in [1]); the oscillation-detector time constant (T_2 in [1]); and the oscillation-detector reset threshold, also described in [1]. These parameters control only the operation of these signal processing blocks, and do not in themselves generate any triggers. Triggers are generated by selecting one of the three outputs of one of the channels in this block as an input to one of the 32 trigger channels. As recommended by Schulz and Laios, the input filtering for this block is the BPA #1 lowpass, described in [2], which is a 12-point Hanning-weighted FIR lowpass filter having a group delay of 0.3 seconds at a 20/second sampling rate.

Signal Functions Available for Triggering

ID#	Function	Update Rate	Channels Available
0	Off	N/A	N/A
1	Voltage	20/sec	A, C, B, Average
2	Current	20/sec	A, C, B, Average
3	Active power (watts)	20/sec	A, C, B, Total
4	Reactive power (VA)	20/sec	A, C, B, Total
5	Apparent power (VA)	20/sec	A, C, B, Total
6	Power factor (PF)	20/sec	A, C, B, Total
7	Sequence voltage components	20/sec	Zero, positive, negative
8	Sequence current components	20/sec	Zero, positive, negative
9	Phase balance ratio, derived from sequence components	20/sec	Zero/positive, negative/positive for both voltage and current
10	Frequency and Time	20/sec	
11	THD, Voltage	1/sec	A, C, B, max(A, C, B)
12	THD, Current	1/sec	A, C, B, max(A, C, B)
13	Harmonic V_{RMS}	1/sec	A, C, B, max(A, C, B)
14	Harmonic I_{RMS}	1/sec	A, C, B, max(A, C, B)
15	K-Factor, voltage	1/sec	A, C, B, max(A, C, B)
16	K-Factor, current	1/sec	A, C, B, max(A, C, B)
17	Flicker, instantaneous, voltage	1/sec	A, C, B, max(A, C, B)
18	Flicker, P_{ST}, voltage	Typ. 1/10 min.	A, C, B, max(A, C, B)
19	Flicker, instantaneous, current	1/sec	A, C, B, max(A, C, B)
20	Flicker, P_{ST}, current	Typ. 1/10min.	A, C, B, max(A, C, B)
21-25	Reserved	TBD	TBD
26-31	Transient detector channels 0-5	20/sec	Bound, rate/change, oscillation

Trigger Channel Parameter Summary (32 channels)

Function	Range or Options
Input signal	0-31, per Signal Functions table (set to 0 if not used)
Channel	0-3, per per Signal Functions table (channels available column)
Trigger dependency	0-2; Off, Active, Inactive
Master channel	0-31, any other trigger channel
Limit type	0-3; x>limit, x<limit, |x|>limit, |x-ref|>limit
Dwell (delay) time	0-65535, 50 ms/count; 0 to 3276.75 seconds
Limit value	Floating point, in measurement units (volts, watts...)
Reference value	Floating point, in measurement units (volts, watts...)

Schulz-Laios Transient Detector Algorithm Control (6 channels) [1]

Function	Range or Options
T_1	Highpass (rate detector) time constant, seconds Default: 0.5 seconds
T_2	Oscillatory detector lowpass time constant, seconds Default: 5 seconds
Oscillatory detector reset threshold	Threshold in measurement units; Default: none
Input signal	0-31, per Signal Functions table
Channel	0-3; per Signal Functions table (channels available column)

[1] **Schulz, Richard P. and Beverly B. Laios,** Triggering Tradeoffs for Recording Dynamics**, *IEEE Computer Applications in Power;* April 1997, pp. 44 ff.**
[2] **Hauer, John F., and Fazlollah Vakili,** An Oscillation Detector Used in the BPA Power System Disturbance Monitor**, *IEEE Transactions on Power Systems*, Vol. 5 No. 1, Feb. 1990, pp. 74 ff.**