

The Sycard USBtest 2000 is a tester for USB ports. It is primarily intended for testing host controllers and hubs in a manufacturing environment. However, its precision testing capabilities and flexible software make the USBtest 2000 quite useful for engineering test and verification applications. This application note discusses the use of the USBtest 2000 in verifying hub operation in the presents of changing frame rates.

The USB revision 1.1 specification defines the frame interval requirements in section 7.1.2 and the hub frame timing requirements in section 11.2. The frame time can be changed by the host so that the USB frames can be synchronized to external events (e.g. to keep audio sample rates in different parts of the system synchronized to prevent underflow or overflow of buffers). To accomplish this, the frame time can be changed by up to one 12 MHz bit clock per every six frames. Hubs are required to track this change. The USBtest 2000 has a test that checks operation with changing frame timing. This test can be used in both hub manufacturing and hub engineering validation environments.

As a manufacturing test, the USBtest 2000 is primarily used to verify that the correct components are assembled correctly and function together. Hubs have an internal time reference that allows them to maintain frame timing in the event that up to two consecutive SOF (Start of Frame) tokens are missed by the hub. This time reference is kept internal to the hub and it can not be measured directly outside of the hub. The USBtest 2000 frequency test verifies that the hub time reference is accurate enough to allow the hub to function over the allowed range of frame timing. This is accomplished by slewing the frame time from the nominal value to a larger number of clocks per frame (for a slower frame rate) and testing traffic both through and to the hub. Then the frame time is slewed to a smaller number of clocks per frame (for a faster frame rate) and again testing traffic both through and to the hub. The frame time is then slewed back to the nominal value. The rate of change of the frame time is the maximum specified in the USB revision 1.1 spec (one bit time per every six frames).

For engineering validation, the same test can be used but the parameters controlling the test can be changed. This allows the engineer to check both the slew rate that the hub can track and the frame time bounds that the hub can lock to. Also the host controller frame accuracy can be explored.

The frame frequency test accuracy is determined by several factors. The tester algorithm measures the time between SOFs with a resolution of .5 microseconds. There is an uncertainty of five counts in the tester and an additional one count quantization uncertainty. The tester time reference itself has an accuracy of 100 PPM. The default is to measure the frequency over 30 frames. With 2000 measurement counts per frame for 30 frames, the default count and quantization uncertainty is 100 PPM. The USB Revision 1.1 specification section 7.1.2 requires the frame rate to be within 500 PPM. The default frequency check limits are 800 PPM to allow for the 500 PPM spec plus 100 PPM measurement uncertainty plus 100 PPM reference accuracy

(with an additional 100 PPM variation allowed). Note that the test can check the frequency for more than 30 frames, which reduces the effect of the count and quantization uncertainty. The maximum usable value for this parameter is 256 frames to make the frequency measurement over.

The frequency test performs the following steps:

- Measure host controller frame size to determine if it is accurate enough to continue with this test sequence.
- Host controller slewed to upper clocks/frames (longer frames, lower frequency)
- Loopback data to tester
- Read hub descriptor several times
- Host controller slewed to lower clocks/frames (shorter frames, higher frequency)
- Loopback data to tester
- Read hub descriptor several times
- Slew to 12000 clocks per frame for (OHCI only)
- Slew to initial frame size (UHCI only)

The parameters controlling the frequency test are given below with the default values shown:

-f800 checks that the host is within 800 PPM of the USBtest clock
 -u12015 upper clocks/frame to step to
 -w11985 lower clocks/frame to step to
 -m11:1 slewing step size in clocks
 -m12:6 number of frames between steps
 -m13:0 final delay (in frames) between the last frequency step and testing
 -m34:30 number of frames to use to measure the host controller frequency

Note that the u and w values are not the values actually programmed into the host controller registers. For UHCI the register value is 11936 less than this, while for OHCI the register value is one less than this. Also, note that since the values shown are the defaults, if they are the desired value then the entire parameter does not need to be entered. The exception to this is that to enable frequency testing the -f option needs to be specified (but the value "800" can be left off, if testing to 800 PPM is desired).

Note that the final step may be smaller than the -m11 parameter, if the total amount of the particular change is not divisible by the step size. For instance, let's use the following example: the nominal is 12000 bit clocks per frame, the step size is set to 7 clocks/frame, and the defaults are used for upper and lower clocks/frame and for the number of frames between

steps. Then the frame sizes will be as follows for the slew from nominal to upper clocks/frames: 12000, 12007, 12007, 12007, 12007, 12007, 12007, 12014, 12014, 12014, 12014, 12014, 12014, 12015. On the next frame after setting the frame size to 12015 in the host controller, the first loopback transfer happens. Since OHCI uses the value in the host controller for the current frame, the first loopback transfer occurs on the second frame with a length of 12015 (if the last step is large, this will usually be the worst case location, as this transfer occurs immediately after the hub has gotten the SOF that occur right after the end of the first frame of the different size). UHCI waits one more frame for the change to take effect, so the first transfer of the loopback occurs on the first frame with the final frame size that is slewed to. Since the frame size is not seen by the hub until the SOF of the next frame, this may not be as stressful to the hub. By using "-m13:1" with UHCI, the transfer can be located at the same place as in the OHCI case.