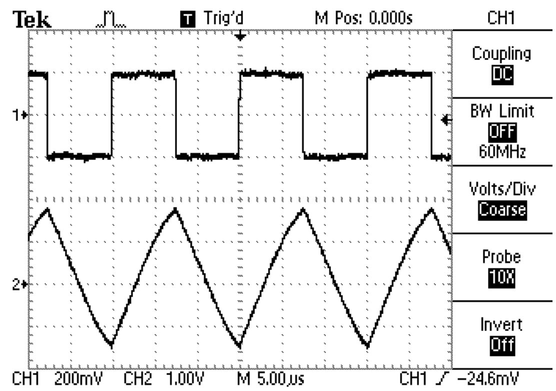
MEASUREMENT TIPS: RISE TIME

The bandwidth-rise time relationship is a quick way to approximate a frequency-domain figure-of-merit (3-dB frequency, f3dB, bandwidth) from a time domain measurement of the 10%-to-90% rise time. BUT, there are some assumptions involved in developing this relationship that you should verify when measuring the rise time of any real circuit.

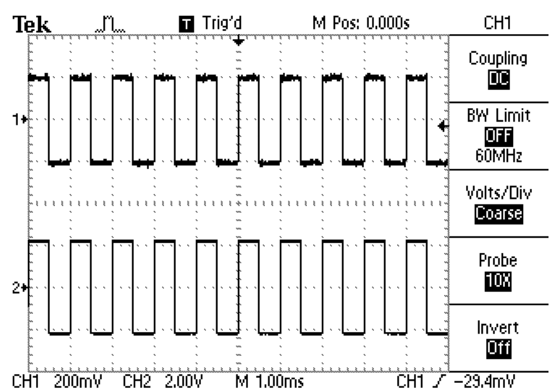
SET UP INPUT
To set up the measurement, use both channels of the scope and display the input and the output waveforms.

WAVEFORM
The input should be a square wave with a rise time much faster than the rise time of the circuit being measured (not a problem for the LM741 op-amp, but can be a problem with very high speed amplifiers). You can check this qualitatively from the scope display.

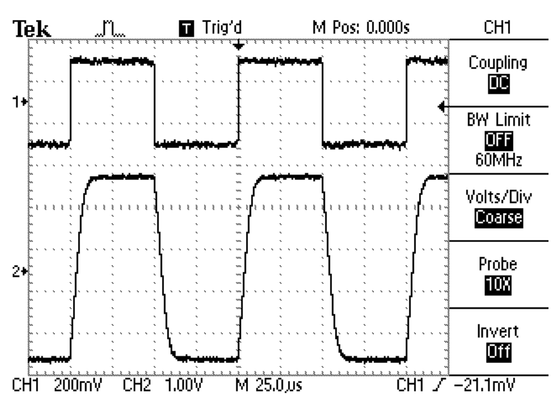
FREQUENCY
The frequency should be low enough that you can see the exponential response "settle" to its final value, but high enough that there isn't an extremely long time between step edges (gives an irritating scope display since you can't see the exponential at all). The exact frequency isn't important - just get a frequency that gives a good display



Frequency too high



Frequency too low



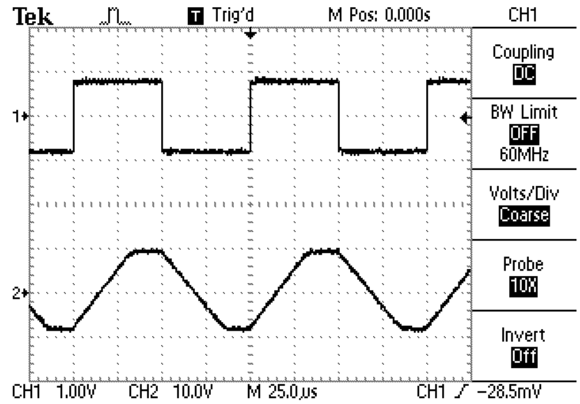
Frequency "just right"

AMPLITUDE

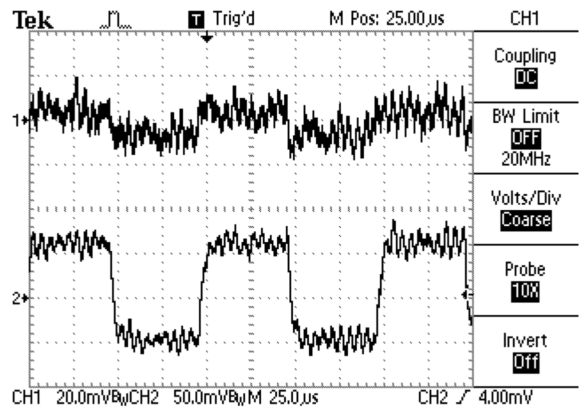
The bandwidth-rise time relationship was derived assuming an exponential step response (single-time-constant linear system). If the input signal amplitude is too large, the output of the system may show slew rate limiting: a step response with a constant slope, rather than an exponential waveform. When slew rate limiting occurs, the rise time is limited by the slew rate of the op-amp, not the bandwidth, and the bandwidth-rise time relationship will not hold. So to avoid measurement error due to slew rate limiting, you want to use a smaller input signal amplitude.

But: if the input signal amplitude is too small, there may be too much noise on the output signal to make an accurate measurement. In general, to avoid measurement error due to noise, you want to use the largest possible signal.

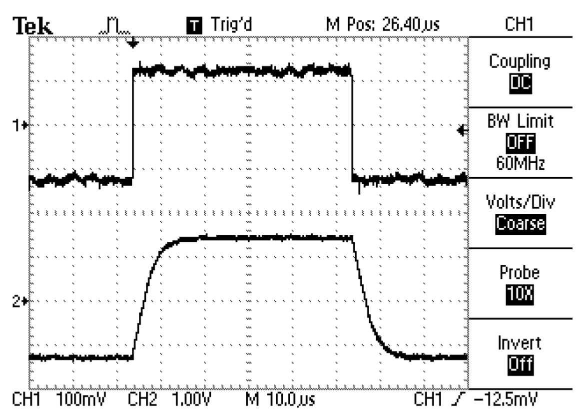
A good compromise is to start with a large signal amplitude, observe the signal qualitatively on the scope, decrease the amplitude until slew rate limiting is no longer observed, and then decrease the amplitude another 10% or 20% just to be sure that slew rate limiting isn't occurring. As we'll see in the measurement part, the actual amplitude isn't important (all measurements are in terms of fractions of the total step amplitude); the important thing is to see an exponential response.



Amplitude too large (slew rate limiting)



Amplitude too small (too much noise)



Amplitude "just right"

RISE TIME MEASUREMENT

For this part, you only need to look at the output signal. Simplify your life by removing the input trace from the scope display, and just look at the output.

Step 1: Vertical scale

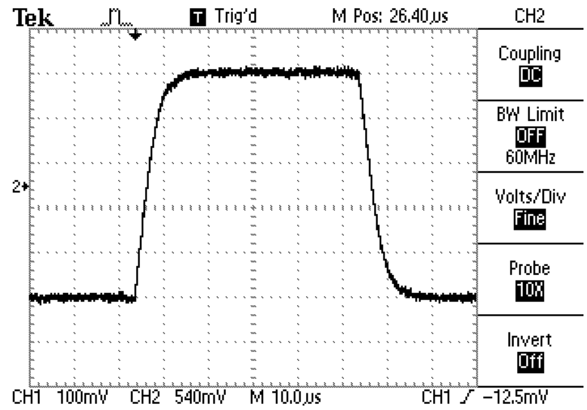
Adjust the vertical scale so the step amplitude is exactly 5 vertical divisions. (You will probably need to use the fine scale adjustment on the vertical scale knob). After this step, each vertical division will represent 20% of the step amplitude.

Step 2: Vertical position

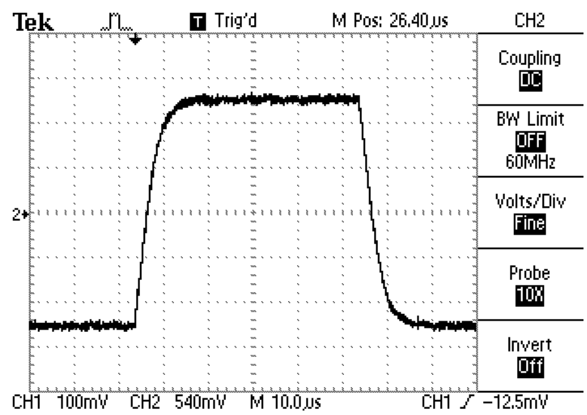
Adjust the vertical position downward by half a division (keeping the same vertical scale) so that the bottom of the step is in the middle of a division, and the top of the step is also in the middle of a division. The waveform will then be crossing division lines at the 10% and 90% of step amplitude points of the step response.

Step 3: Horizontal scale / position

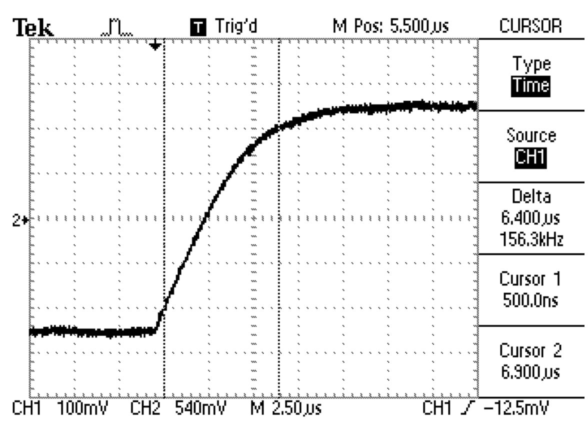
Adjust the horizontal scale and horizontal position so that the rise time takes up at least a few horizontal divisions (to get good resolution on the time measurement). The rise time is the ΔT between the 10% and 90% crossing points of the step response; measure with the time cursors if available.



Initial, final values on gridlines



Move down 1/2 division: 10%, 90% points on gridlines



Rise time: Cursor Delta = 6.4 µs between 10%, 90% points.