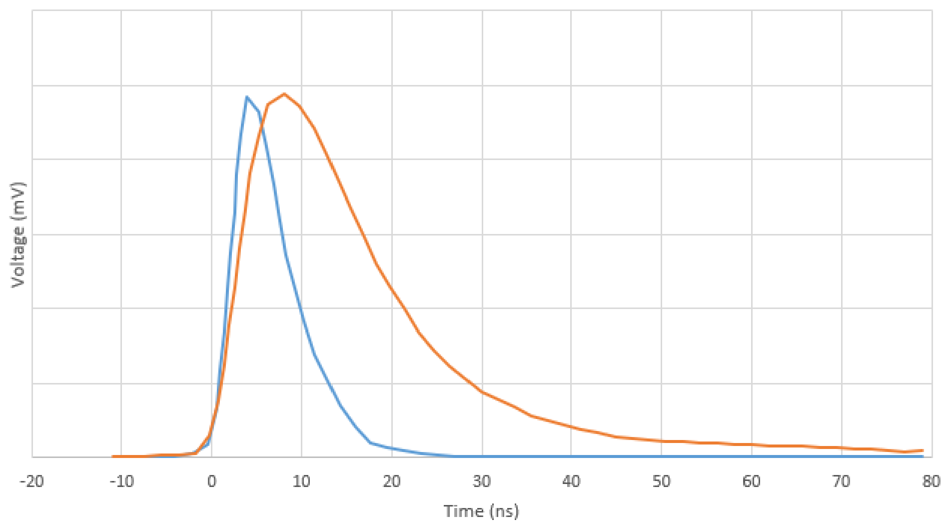
Why Pulse Rise & Fall Times are Different in Photodetector Measurement

Jeff Winkler, Project Engineer
Electro-Optics Technology, Inc., 3340 Parkland Ct. Traverse City, MI 49686, USA

The output pulses of PIN photodetectors tend to have a fall time that is longer than the rise time, as shown in the example below:



There are several factors that can contribute to this effect:

1. Photocarrier transit effects
2. Diffusion current
3. Saturation
4. Circuit design

Photocarrier Transit Effects

The absorption region of a PIN photodiode acts like a capacitor. When photons are absorbed, electrons and holes are generated and then swept toward opposite ends of the device by the applied electric field that is generated by the bias voltage.

Immediately after absorbing the pulse, an equal number of electrons and holes travel in opposite directions. These moving carriers lead to displacement current at the photodiode terminals. Since electrons travel more quickly than holes in most semiconductors, the electron response results in a fast rise and fall time component, but the slower holes continue to contribute current after the electron current has been collected. This leads to a "tail" on the falling edge. Although this can be optimized by selecting diode absorption layer material, thickness, and device area, trade-offs are typically observed, such as responsivity and bandwidth.

Diffusion Current

There are two main mechanisms for charge carrier transport (current) in semiconductors: drift current and diffusion current. Drift current is produced by the charge carriers (electrons and holes) moving in response to an electric field.

Diffusion current occurs because of movement of charges (holes or electrons) due to non-uniform concentrations of charge carriers in the device. Typically, diffusive transport is much slower than drift. In a PIN photodiode, the design is typically intended to have the absorption occur in a region of high electric field so that current is dominated by drift. However, several factors can lead to diffusion-related current in photodiodes. Illuminating the diode outside of its intended active area can lead to carriers being photogenerated in low-field regions that can then diffuse to the active region before being collected. Use of a photodiode at wavelengths away from the design wavelength can also lead to diffusive current components since carriers can be photogenerated outside of the intended absorption region.

Saturation

Illuminating a photodetector with too much optical power can exacerbate transit-time effects. The large amount of photo-generated charge in the absorption region screens the electric field, lowering the charge carrier velocity and, thus, broadening the output pulse. This is accompanied by a reduction in the speed of the detector's temporal response.

Circuit Design

The packaging of the detector can introduce parasitic capacitance and inductance, which discharge through the load. Parasitic inductance in particular can lead to ringing and arises typically from wire bonds, cables, and other wiring within the detector and measurement circuitry. Parasitic capacitance comes from the board dielectric, cables, and connectors. It is recommended to minimize the length of your coaxial cable and use a cable rated at a higher bandwidth than your measurement bandwidth. These effects can cause not only asyemmtry on rising and falling edges, but also ringing and "ghosting" in the signal. Minimizing the use of adapters (e.g. between different connector types) and ensuring the proper termination impedance are critical to achieving the best performance. If adapters are required, use high-quality adapters that exceed the measurement bandwidth or use high-quality cable with the appropriate connectors installed.

Summary

All parts of the measurement system, including the diode, support circuitry, bias voltage, connectors, cables, and instruments have an effect on the overall observed shape of the electrical pulse. For the most accurate representation of pulse shape, it is recommended that the components have a bandwidth ten times greater (or a rise time ten times less) than the incoming pulse rise time (bandwidth = 0.35/rise time for a Gaussian pulse). This guarantees that the effect of the measurement system will be minimal and will allow an accurate representation of all of the high-frequency components that make up the pulse. In practice, this recommendation might not be possible for some components due to cost or unavailability; users must be aware that pulse shape will be compromised in these cases. Detectors with specifications near or longer than the pulse parameters will broaden the pulse and reduce its amplitude. This is due to attenuation of the higher frequency components of the pulse. Use of an incorrect terminating impedance (e.g. using a large terminating impedance for a photodetector designed for 50 Ω) will also broaden the pulses.

For more information on this or any of EOT's products, please contact us at sales@eotech.com or +1.231.935.4044.