APPLICATION NOTE

PYROELECTRIC DETECTORS
A PERFECT MATCH FOR YOUR PULSED LASER!

"Why is that" you say? A pyroelectric detector is basically a fast, AC current source whose output is driven by *dT/dt* (rate of change of temperature over time). Its response to an optical impulse is nearly instantaneous (i.e. sub nanosecond), limited only by the rate of heat transfer through its front metallic absorbing coating. Add an organic black coating and it slows down a little (i.e. sub microsecond).

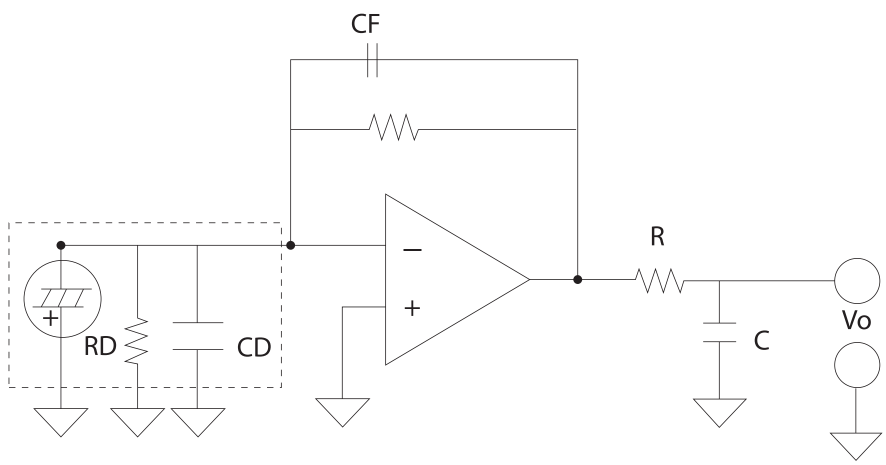
Need to measure from a few nanojoules to several hundred millijoules?
➔ **No Problem!**
Need to measure a single pulse or pulses at up to 300,000 pps?
➔ **No Problem!**
Need to measure microsecond to femtosecond pulse widths?
➔ **No Problem!**
Need to measure pulses in the DUV, VIS, Near IR, Mid IR, Far IR or even THz?
➔ **No Problem!**

Needless to say, a Pyroelectric Detector makes a very versatile laser Joulemeter.

SO HOW DOES IT WORK?

We can design a passive or active joulemeter circuit for the Pyroelectric Detector. We've selected an active circuit for this technical note. It has the advantage of performance independent of cable length. We select component values to achieve a desired voltage responsivity, rise and fall time.

Here's a look at a typical circuit for a Pyroelectric Joulemeter:



APPLICATION NOTE

And here are the basic equations that govern its performance as a Joulemeter. **The Voltage Responsivity R_v** of the probe can be expressed as the ratio of the detector element's Current Responsivity R_i and the Feedback Capacitor C_f as expressed by:

$$R_v = \frac{R_i}{C_f} \quad \frac{Volts}{Joule}$$

The **Fall Time Tau** of the joulemeter is the RC Time Constant R_f of the feedback resistor times the Feedback Capacitor C_f:

$$Tau = R_f C_f$$

The **Rise Time T_{rise}** of the pulse, defined as 10% to 90%, can be set by a filter on the output of the amplifier:

$$T_{rise} = 2.2 \cdot RC$$

The scope trace below (Figure 1), shows a typical voltage pulse from our QE8SP-B-BL Pyroelectric Joulemeter (Figure 2).

The measured voltage output, from the peak to the baseline is directly proportional to the pulse energy and very linear, as long as the pulse width is less than 10% of the RC Time Constant.

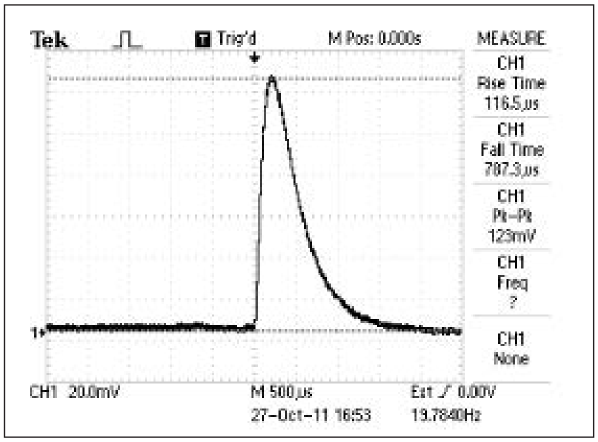


Figure 1: Typical voltage output for QE8SP-B-BL Joulemeter

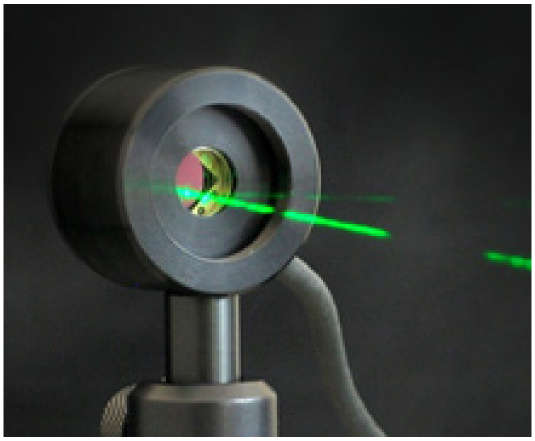


Figure 2: QE8SP-B-MT Pyroelectric Joulemeter

An important "rule of thumb" to remember is that the pulse width must be a least 10 times shorter than the *RC* time constant of the integrating pyro circuit. This will result in non-linearity of less than 5%. A pulse that is 50 times shorter will result in non-linearity of less than 1%.

APPLICATION NOTE

WHY NOT USE A SEMICONDUCTOR PHOTODIODE AS A JOULEMETER?

A Silicon Detector may indeed be a good choice if you are measuring in the UV, VIS or Near IR and at energy levels of a **few microjoules or less**. In fact, we offer Silicon, Germanium and InGaAs Joulemeter probes that can be used to measure down to 100 femtojoules. However, these detectors have their short comings!

1. **Photocurrent saturation:** All photodiodes exhibit photocurrent saturation, which means that at some level of laser energy or average power, the photodiodes can't produce any more current. They become non-linear before reaching this point. This can occur at a few microjoules or at average powers greater than 1 mW, depending in part on the pulse width.

2. **Use of ND filters:** Avoiding saturation requires use of optical attenuation, like ND filters. Optical attenuators have their own set of problems, like spatial non-uniformity, angle dependence, and temperature sensitivity.

3. **Wavelength response vs Reverse bias:** For use in the Near IR region (900 to 1100 nm), a Silicon detector must be operated in a reverse biased (photoconductive) mode. Otherwise, the response time of the detector will vary with the wavelength of the source and create integration errors.

4. **Temperature coefficient:** The current responsivity of Silicon detectors include a temperature coefficient. It is minimal, 0.1%/°C, from 200 to 900 nm, but can be as much a 1%/°C at 1064 nm.

5. **UV degradation: Measuring a UV laser?** You'll also have to worry about UV degradation of the semiconductor detectors. Degradation can happen in minutes, hours, or days depending on the particular type of photodiode and level of UV radiation.

In summary, Pyroelectric Detectors don't exhibit any of these shortcomings.

So, if you have sufficient pulse energy, greater than 50 nanojoules, you'll likely want to choose a Pyroelectric detector for your Joulemeter.

PYROELECTRIC DETECTORS TO THE RESCUE!

Let us site one example of a DUV laser application where two Pyroelectric Detectors came to save the day!

A Medical Laser company, whose system is based on a pulsed, DUV Excimer laser, had designed a 2-channel Joulemeter using Silicon photodiodes. It was designed as a diagnostic to monitor the pulse energy in two different optical legs of the system. They wanted to know when their optics were degrading and their effect on the system performance. Soon, they started having problems getting consistent measurements and started suspecting that their optics had degraded. So they sent several back to their optical vendor, only to have them prove that the optics had not changed. Their UV optical throughput was the same as when new! As the Medical Laser company started to investigate what might have mislead them, they found that the "UV hardened" Silicon detectors were the problem. They were the ones degrading over time, not the optics!

This company had experience using large area Pyroelectric Joulemeters for external energy measurement and decided to investigate their use for the onboard 2-channel diagnostic application. They designed and built several systems using two of our QS5-H discrete Pyro Detectors, and their problems were solved!