CHAPTER 3

BASIC OPERATING METHODS OF PHOTOMULTIPLIER TUBES

This section provides the first-time photomultiplier tube users with general information on how to choose the ideal photomultiplier tube (often abbreviated as PMT), how to operate them correctly and how to process the output signals. This section should be referred to as a quick guide. For more details, refer to the following chapters.

3.1 Using Photomultiplier Tubes

3.1.1 How to make the proper selection

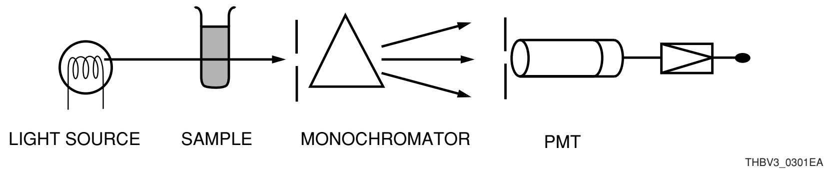

Figure 3-1: Atomic absorption application

Figure 3-1 shows an application example in which a photomultiplier tube is used in absorption spectroscopy. The following parameters should be taken into account when making a selection.

Incident light conditions	Selection reference	
	<Photomultiplier tubes>	<Circuit Conditions>
Light wavelength	Window material Photocathode spectral response	
Light intensity	Number of dynodes Dynode type Voltage applied to dynodes	Signal processing method (analog or digital method)
Light beam size	Effective diameter (size) Viewing configuration (side-on or head-on)	
Speed of optical phenomenon	Time response	Bandwidth of associated circuit

It is important to know beforehand the conditions of the incident light to be measured. Then, choose a photomultiplier tube that is best suited to detect the incident light and also select the optimum circuit conditions that match the application. Referring to the table above, select the optimum photomultiplier tubes, operating conditions and circuit configurations according to the incident light wavelength, intensity, beam size and the speed of optical phenomenon. More specific information on these parameters and conditions are detailed in Chapter 2 and later chapters.

3.1.2 Peripheral devices

As shown in Figure 3-2, operating a photomultiplier tube requires a stable source of high voltage (normally 1 to 2 kilovolts), voltage-divider circuit for distributing an optimum voltage to each dynode, a housing for external light shielding, and sometimes a shield case for protecting the photomultiplier tube from magnetic or electric fields.

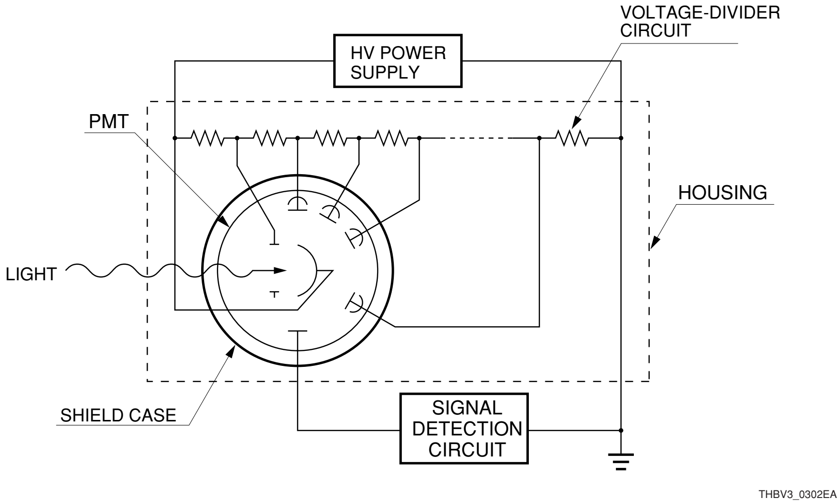

Figure 3-2: Basic operating method

High-voltage power supply

A negative or positive high-voltage power supply of one to two kilovolts is usually required to operate a photomultiplier tube. There are two types of power supplies available: modular power supplies like that shown in Figure 3-3 and bench-top power supplies like that shown in Figure 3-4.

C4900
High voltage output: -1250 V
Current output: 600 µA

Figure 3-3: Modular high-voltage power supply

C9525
High voltage output: -2000 V
Current output: 2 mA

Figure 3-4: Bench-top high-voltage power supply

Since the gain of photomultiplier tubes is extremely high, they are very susceptible to variations in the high-voltage power supply. If the output stability of a photomultiplier tube should be maintained within one percent, the power supply stability must be held within 0.1 percent.

Voltage-divider circuit

Supply voltage must be distributed to each dynode. For this purpose, a voltage-divider circuit is usually used to divide the high voltage and provide a proper voltage gradient between each dynode. To allow easy operation of photomultiplier tubes, Hamamatsu provides socket assemblies that incorporate a photomultiplier tube socket and a matched divider circuit as shown in Figures 3-5 to 3-8.

(1) D-type socket assembly with built-in divider circuit

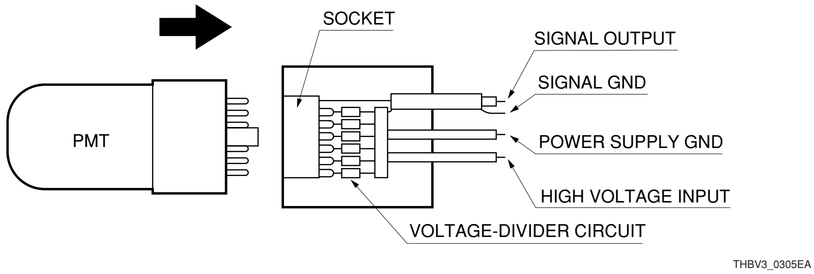

Figure 3-5: D-type socket assembly

(2) DA-type socket assembly with built-in divider circuit and amplifier

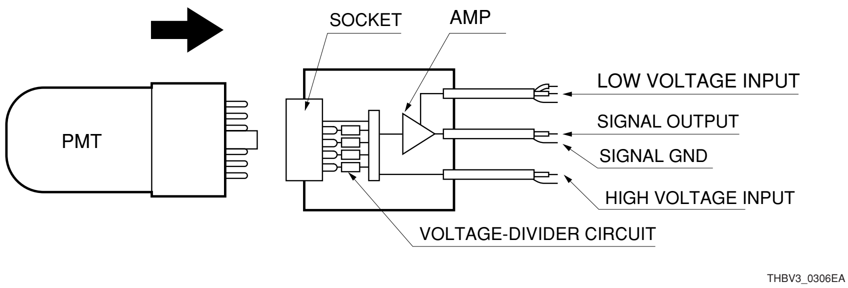

Figure 3-6: DA-type socket assembly

(3) DP-type socket assembly with built-in voltage divider and power supply

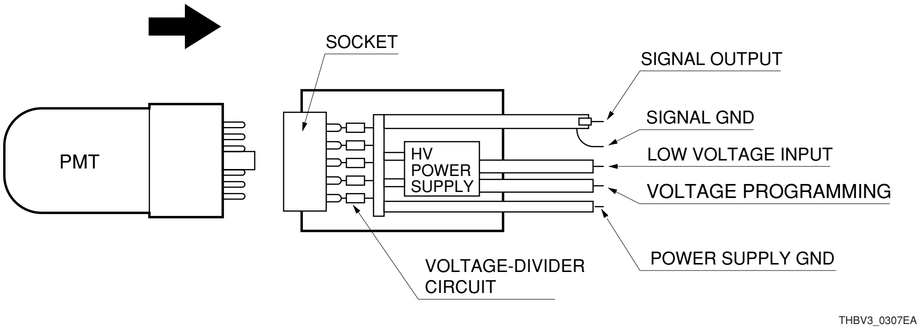

Figure 3-7: DP-type socket assembly

(4) DAP-type socket assembly with built-in voltage divider, amplifier and power supply

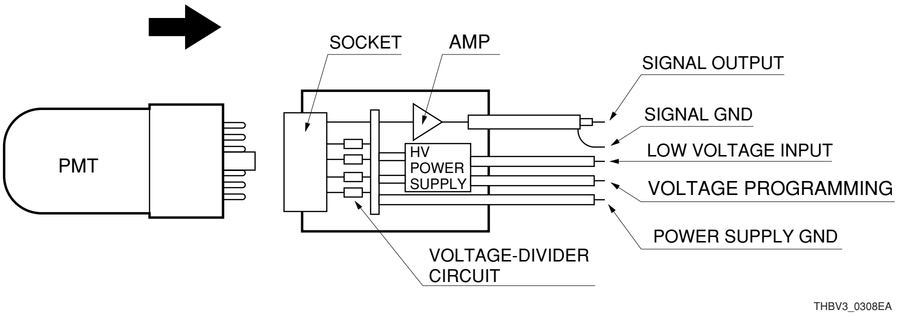

Figure 3-8: DAP-type socket assembly

Housing

Since photomultiplier tubes have very high sensitivity, they may detect extraneous light other than the light to be measured. This decreases the signal-to-noise ratio, so a housing is required for external light shielding.

Photomultiplier tube characteristics may vary with external electromagnetic fields, ambient temperature, humidity, or mechanical stress applied to the photomultiplier tube. For this reason, a magnetic or electric shield is also required to protect the photomultiplier tube from such adverse environmental factors. Moreover, a cooled housing is sometimes used to maintain the photomultiplier tube at a constant temperature or at a low temperature for more stable operation.

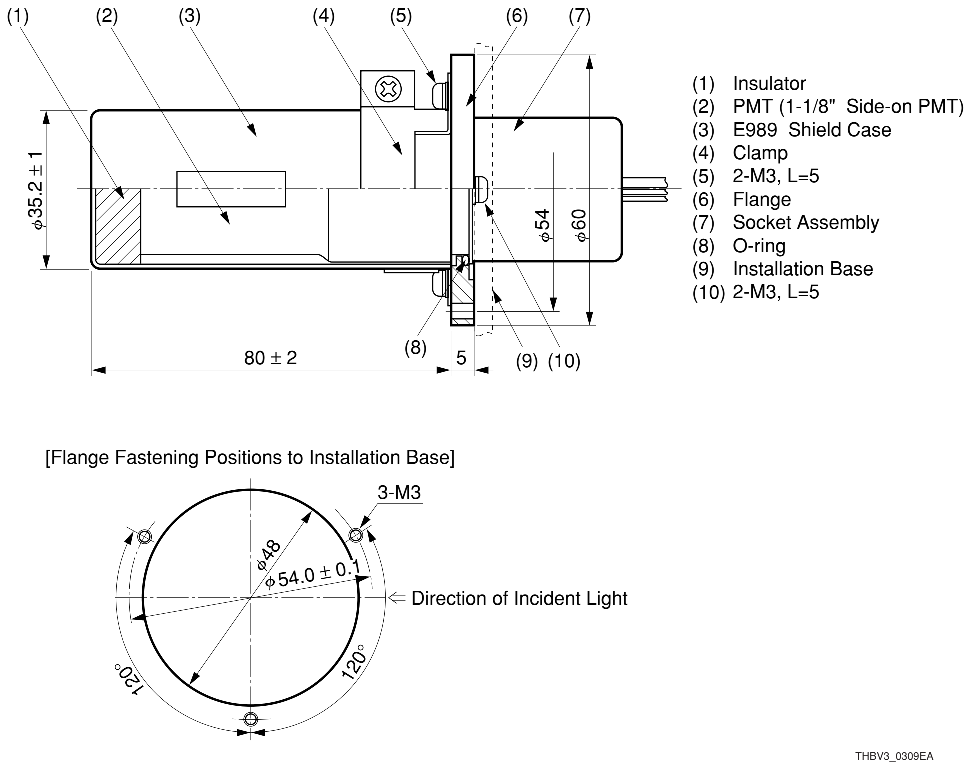

Figure 3-9: Housing example (with built-in magnetic shield case)

Integral power supply module

To make the use of photomultiplier tubes as easy as possible, Hamamatsu Photonics provides PMT modules which incorporate a photomultiplier tube in a compact case, along with all the necessary components such as a high-voltage power supply and operating circuit. (Figure 3-10)

PMT modules are easy to handle since they operate by supplying only low voltage, making the equipment compact and simple to use.

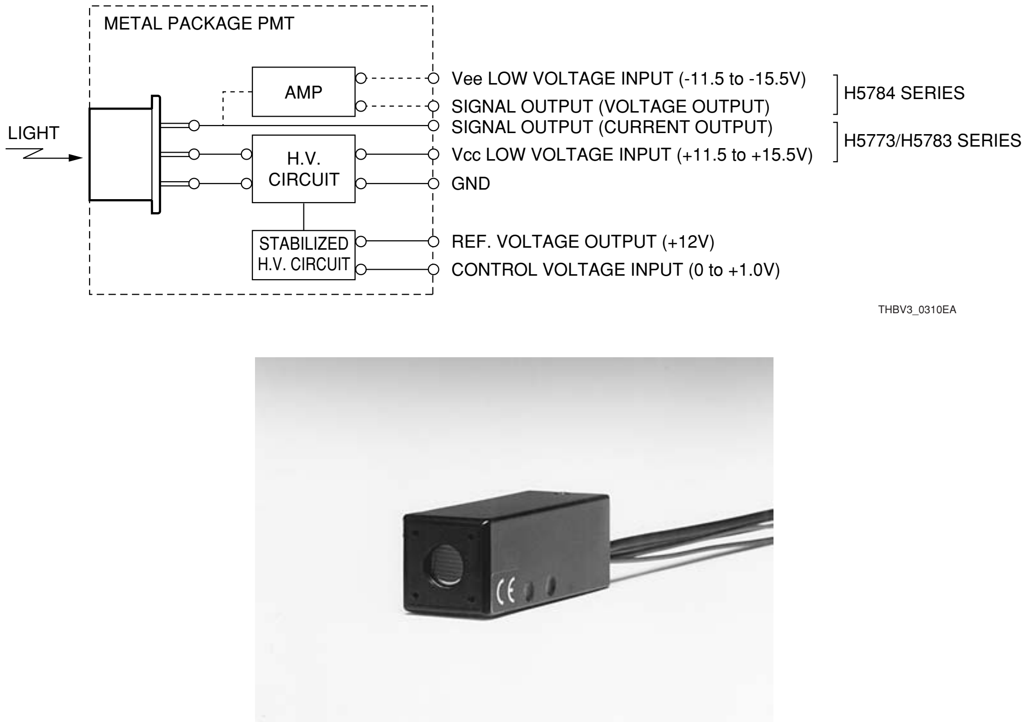

Figure 3-10: Structure of an integral power supply module

Various types of PMT modules are available, including those that have internal gate circuits, photon counting circuits or modulation circuits. Refer to Chapter 8 for detailed information.

3.1.3 Operating methods (connection circuits)

The output from a photomultiplier tube can be processed electrically as a constant current source. It is best, however, to connect it to an optimum circuit depending on the incident light and frequency characteristics required. Figure 3-11 shows typical light measurement circuits which are commonly used. The DC method and AC method (analog method) are mainly used in rather high light levels to moderate light levels. At very low light levels, the photon counting method is most effective. In this method, light is measured by counting individual photons which are the smallest unit of light.

The DC method shown in Figure 3-11 (a) detects DC components in the photomultiplier tube output by means of an amplifier and a lowpass filter. This method is suited for detection of relatively high light levels and has been widely used. The AC method shown in (b) extracts only AC components from the photomultiplier tube output via a capacitor and converts them into digital signals by using an AD converter. This method is used in regions where modulated light or light intensity is low and the AC components are predominant in the output signal over the DC components. In the photon counting method shown in (c), the output pulses from the photomultiplier tube are amplified and only the pulses with an amplitude higher than the preset discrimination pulse height are counted as photon signals. This method allows observation of discrete output pulses from the photomultiplier tube, and is the most effective technique in detecting very low light levels. Other measurement methods include a lock-in detection technique using an optical chopper, which features low noise and is used for detecting low-light-level signals.

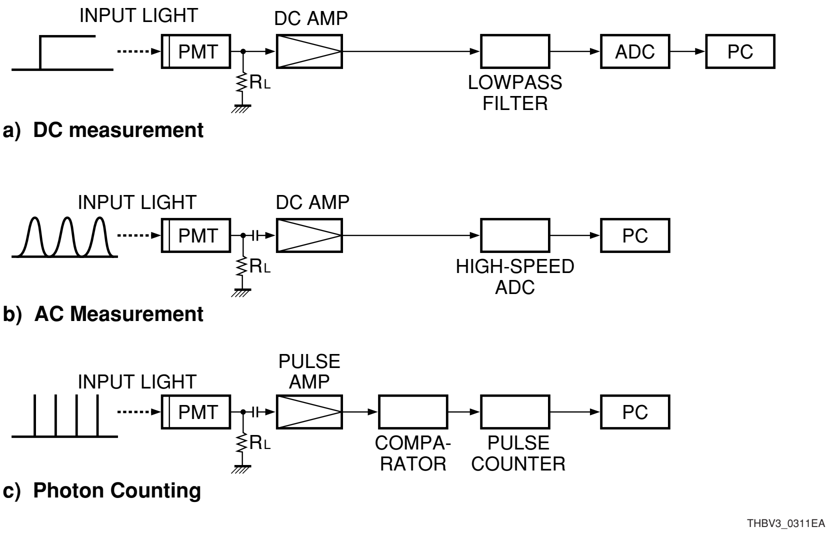

Figure 3-11: Light measurement methods using PMT

These light measurement methods using a photomultiplier tube and the connection circuit must be optimized according to the intensity of incident light and the speed of the event to be detected. In particular, when the incident light is very low and the resultant signal is small, consideration must be given to minimize the influence of noise in the succeeding circuits. As stated, the lock-in detection technique and photon counting method are more effective than the DC method in detecting low level light. When the incident light to be detected changes in a very short period, the connected circuit should be designed for a wider frequency bandwidth as well as using a fast response photomultiplier tube. Additionally, impedance matching at high frequencies must also be taken into account. Refer to Chapters 5 and 6 for more details on these precautions.