477 AC Current Preamplifier
User Notes

BENTHAM

Overview

The 477 is used as a pre-amplifier for a lock-in amplifier in AC systems employing current source detectors such as photomultipliers and photodiodes (e.g. Si, Ge, InGaAs, InSb) which, at low frequencies, give their best performance when connected to a virtual ground. The 477 consists of a six decade (10^8 to 10^3 V/A) trans-impedance amplifier based on an operational amplifier followed by a voltage amplifier.

The input, which is DC coupled, effectively has zero impedance consequently no voltage is generated across the detector as a result of the photocurrent it produces.

This short circuit operation enhances linearity of detectors and reduces the effect of cable capacitance.

The unit has two inputs which can be selected via the USB interface and is typically housed in the Bentham 417(T): power supply, USB interface and display.

Mounting

The 477 is normally supplied already mounted in the Bentham 417 bin/power supply unit. If you are fitting a 477 into an existing 417 you should refer to the 417 manual which provides information on the installation procedure and on the preferred position of the 477 within the 417. In order to avoid introducing additional noise the output of the 477 is not connected to any of the 417 bus lines.

Electrical Connection

Connection should be made from the output of the 477 to the voltage input of the lock-in amplifier using a BNC-BNC cable. If the 477 is supplied in a system Connection between the 277 input or inputs and detector or detectors should be made using low microphony BNC-BNC cables. Do not make these cables unnecessarily long. Bentham recommend a maximum length of 2m.
with a Bentham 485 lock-in amplifier the short connecting cable required will be supplied.

Manual Operation

All the functions of the 477 can be controlled manually from the front panel. The present gain range is indicated by an amber LED, range overload by a red LED and the selected input by a green LED.

Whilst this amplifier is typically computer controlled via USB/I^2C, it is possible to operate locally, by depressing the black remote button. One may change the present gain range by depressing the upper and lower gain range buttons and change the input used using the IP1/IP2 button.

The sensitivity range selected and input in use are indicated by yellow and green leds respectively. The input, the green led and the characters used for sensitivity control are linked by lines on the front panel of the module.

Rotating the knob in the clockwise direction increases sensitivity until the maximum sensitivity has been reached i.e. range p or P. Turning the knob one more step in the clockwise direction then changes the input in use. After the change in input there is one unused step of the switch before range changing re-commences at the minimum sensitivity.

The output of this amplifier, 0-10V, is input directly to the ADC. The output is also supplied to the 417(T) bin display channel C.

Use with Detectors

The ideal current generator has infinite source impedance, yet in practice all detectors have a finite impedance (shunt resistance). For photomultipliers and silicon photodiodes the shunt resistance can be ignored, however, for some other detectors, such as room temperature germanium (shunt resistance ~100kΩ), it may be seen that use of the most sensitive ranges of the 487 leads to a positive or negative offset appearing at the output. Detectors which give rise to these offsets are better used with chopped light source and a current sensitive lock-in amplifier (Bentham 477 + 485). The 277 is primarily intended for use with current source detectors including photomultipliers and photodiodes.

When used with these devices connection should be made from the inner of the input socket directly to the anode in the case of pmts and to the anode or cathode in the case of photodiodes. Do not use a load resistor.

In the case of PMTs the dynode chain should be arranged for negative high voltage operation with the anode at ground. The required circuits are as follows:-

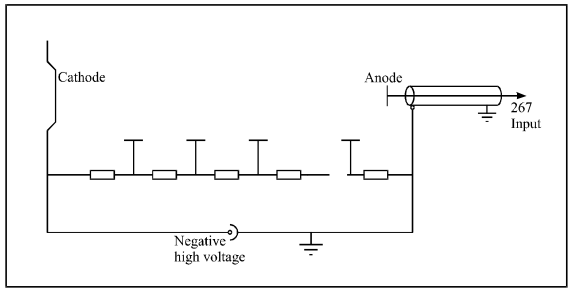

Figure 1: Photomultiplier

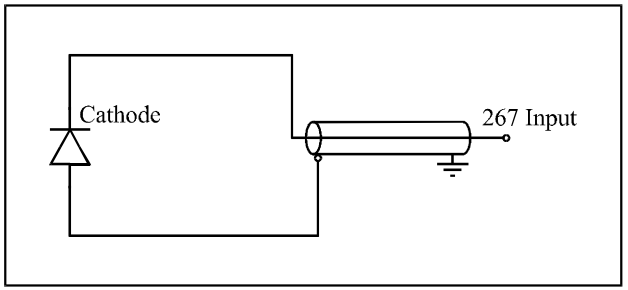

Figure 2: Photodiode

CAUTION

It is not possible to protect a current sensitive input from damage caused by connection to high voltage. Connection of the 477 input to any part of a pmt high voltage circuit other than that indicated above may result in destruction of the 477.

Current Sinking
The following block diagram shows a typical chopped light detection system using the 477 pre-amplifier and a lock-in.

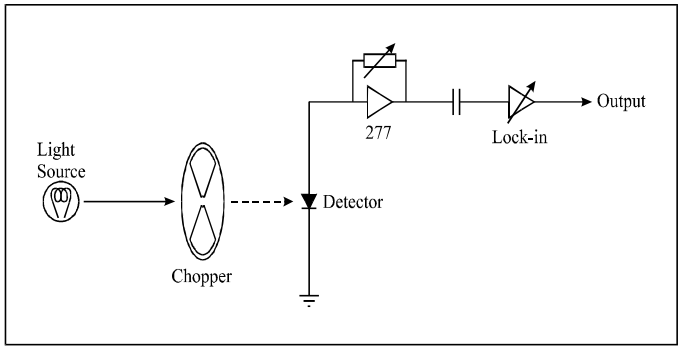

Figure 3

The important points to note are that the input of the 477 is DC coupled while the input to the lock-in is AC coupled.

The input of the 477 must be dc coupled so that short circuit operation of the detector is maintained under all conditions. The input to the lock-in is ac coupled so that only the AC component of the signal, that due to the chopped light, is seen by the lock-in.

In general, the best signal to noise performance will be achieved with as much of the gain as possible being provided by the current amplifier and the remainder by the lock-in. In practice however, many infra-red detectors produce a standing dc current which at low light levels is much larger than the ac signal. This standing dc current will cause saturation in the 477 at higher gain settings and hence will limit the amount of gain which can be provided.

The availability of programmable gain in both the pre-amplifier and the lock-in allows the best compromise to be made between these two conflicting constraints.

For any signal level the optimum performance will be achieved by setting the 477 to the highest gain possible without causing saturation and providing the remainder of any gain required with the lock-in.

The ability of the combination of the pre-amplifier and lock-in amplifier to accommodate a large dc current at the input while measuring a small ac component is referred to as current sinking.

Operating Frequency
Because the 477 is followed by a phase sensitive device (a lock-in) it is important that the operating frequency is not close to the upper bandwidth limit as this would introduce a phase shift into the signal. For the 477, which has an operating range of 5kHz, problems would not be expected with typical chopped light systems operating at a few hundred Hz.

However, it should be noted that the bandwidth of all current amplifiers is reduced when the input is loaded by, for example, the shunt resistance of a detector. The degree to which the bandwidth is reduced increases as the gain increases so it is possible to have a situation where the operating frequency is close to the bandwidth limit on the higher gain ranges but not on the lower gain ranges. This could result in a range dependent phase shift in the signal passed to the lock-in amplifier.

In practice, detectors with low shunt resistance also usually give high leakage currents which preclude the use of the higher gain settings of the current amplifier. However, if a range dependent phase shift is seen this possible cause should always be considered.

Possible cures include using lower sensitivity ranges of the current amplifier (i.e. increasing the lock-in gain), reducing the chopping frequency or changing to a detector with a lower shunt resistance.

Overload
A red led lights when the 477 output exceeds +10V or -10V. Note that when the 477 is in DC overload no AC signal will be passed to the lock-in amplifier the output of which would therefor fall to zero. In a computer controlled system the software would interpret this as a low signal condition and respond by increasing the gain driving the 477 even further into overload.

In this otherwise unrecoverable situation the overload information available from the 477 can be used to return the system to normal operation. Overload information is returned in response to a USB read or enter, the returned character being zero for safe operation and 1 for overload.

Block Diagram

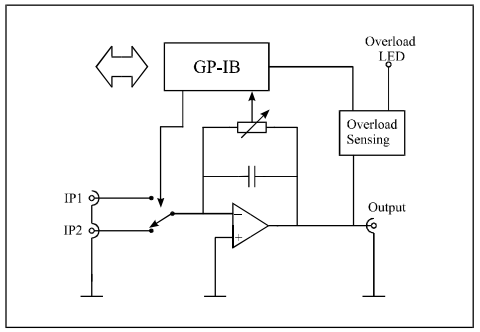

Figure 4

Applications
The 477 is used in chopped light spectral measurement systems employing current source detectors such as photomultipliers and photodiodes of the following types: Si, Ge, InGaAs & InSb.

The following diagram shows a typical spectroradiometer using silicon and indium antimonide photodiodes to cover the wavelength range from 300nm to 5.5µm.

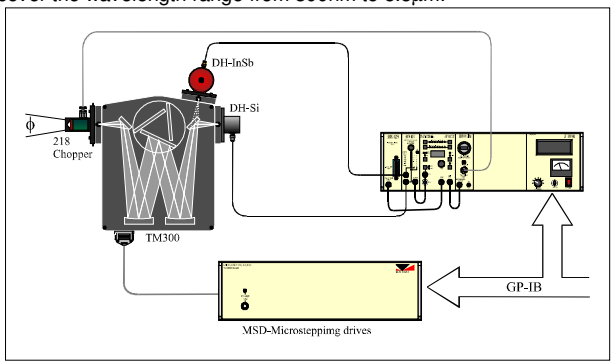

Figure 4: Chopped Light Spectral Measurements

Trouble Shooting

SYMPTOM	POSSIBLE CAUSES
The 477 does not respond to any USB commands.	The 477 is set to the wrong USB address. The 477 is not connected to the USB interface.
No leds are illuminated on the 477 front panel.	The power connection from the 477 is not connected to the 2417 motherboard.
Signal is expected from the detector but there is little or no output from the lock-in.	The wrong input has been selected either on the 477 or on the lock-in or there is no connection between the 477 and lock-in If the detector is a photomultiplier the high voltage is switched off see The lock-in is not phased correctly see 485.
The 477 is showing overload but there is no output from the lock-in.	The 477 has been driven into saturation by leakage current from the detector and is no longer passing the ac component of the signal to the lock-in.
Although the chopping frequency is less than 1kHz there seems to be a phase change associated with changing gain on the 477.	

WEEE statement

Bentham are fully WEEE compliant, registration number is WEE/CB0003ZR. Should you need to dispose of our equipment please telephone 0113 385 4352 or 4356, quoting account number 135419.

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