



To: Ms. Anna Passera – European Commission
From: Fred P. Rohrbacher
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Re: Support for Marshall RoHS Cd exemption request

Support for Marshall RoHS exemption request for cadmium in opto-couplers

Introduction

This submission is in support of the exemption requests for cadmium in opto-electronic components submitted by Marshall Amplification which is in the current Stakeholder Consultation. Cadmium sulphide/selenide photocells are sensitive to visible light and currently have a wide variety of uses such as night lights, street lighting controls and in CdS (cadmium sulphide) opto-couplers. Cadmium sulphide/selenide photocells are used in professional analogue audio amplifiers because the alternative visible light detectors cannot be used for technical and scientific reasons which are explained in this submission.

Background to CdS

Cadmium Sulphide (CdS) and cadmium sulphide/selenide (CdS/Se) mixtures are semiconductors, but they are not usually used in the same way as the most familiar semiconductor, namely silicon. These are used as photoconductors, which means that their resistances changes in response to incident light. Photoconductivity refers to the phenomenon where light falling on a material increases its electrical conductivity. The material has to be a semiconductor with a band gap smaller than the energy of the light falling on it. The process occurs because the light is absorbed by electrons and they are lifted out of the valence band into the conduction band. These conduction electrons and their corresponding holes in the valence band increase the electrical conductivity.

A photoconductor does not generate a voltage, as does a photodiode. It is passive but can be made sensitive to small changes in light level.

Properties of CdS/Se

CdS is one of the most important photoconductors. It has been used as a photoconductor for about 50 years and there is a well established technology for making these sensors. CdS has a peak response in the blue and green. A similar material, cadmium selenide (CdSe) has a peak response in the red. By mixing these materials, the electrical response to a range of wavelengths can be made similar to that of the human eye. This has invaluable implications for all occasions where light levels need to be measured in the same way that the human eye sees light.

The response time for the increase in conductivity is not very rapid. This might be thought to be a disadvantage, but the property has been exploited in opto-couplers used in professional audio as discussed in section 4.2. By suitable mixing of materials and processing, the peak response, the resistance, the temperature coefficient of resistance, the turn-on time and the turn-off time can all be controlled. It is usually used in the form of evaporated or printed layers.

CdS photosensors have several unique and extremely useful features, including:

1. The electrical response is not excessively fast. This means that the electrical output will not be affected by short flashes of light. Silicon photodiodes and transistors as well as other types of photoconductor all have very fast response and this is a disadvantage in audio applications as “electrical noise” is not eliminated.
2. The electrical response is a regular linear function of the input light level.

3. They have very large dynamic range which means that they can respond to a much larger range of light levels, typically giving a response from 0.02 Lux to over 10,000 Lux and respond to these levels with an equally large range of resistance. Resistance values are typically from 2Ω to $50\text{ M}\Omega$. Photodiodes respond to much smaller ranges of light levels.

Analogue optocouplers for audio equipment

The general term optocouplers covers those devices that transmit information between two parts of an electronic circuit without any electrical connection, but by means of light. This is important where it is necessary to electrically isolate one part of a circuit from another but pass a signal without electrical interference. They are also used to isolate high voltage circuits from low voltage circuits for safety of users. The most common optocouplers are effectively used as switches. The output is either on or off, and so they are ideal for transmitting digital information. Opto-couplers (non-CdS types) use a light emitting diode (LED) on the input side and a silicon photodiode, phototransistor or phototriac on the output. The light from the LED is coupled into the sensor and turns it on. Phototriacs are either on or off. Photodiodes and phototransistors have an output dependent on the light level from the LED.

Analogue CdS optocouplers use an LED on the input end and a CdS photoconductor on the output. These components are used widely in the professional audio industry. One of the unique features of this component is that the photoconductor can operate with alternating as well as direct voltages across the output, because the photoconductor is entirely a passive device. They can operate with very low voltage or very high, up to one 6000V is possible. Photodiodes and phototransistors operate in a completely different way and so cannot be used as substitutes. Where they are used, the circuits used are completely different, usually having more electrical components to provide a similar function although with limitations in performance. The photoconductor can be set up with a fast turn-on and a slow turn-off to match the required audio response all in one component without the need for additional optical or electronic components. With a normal potentiometer for volume control, there can be momentary loss of contact, which gives an audible sound. This may still occur on the current driving the LED on the input side, but by suitable adjustment of the response times, the output can ignore these errors, giving a smooth response.

The component is used for mixing desks, high end analogue audio for “compression”, for loudspeaker protection, for battery operated radio microphones, for current control of professional audio amplifiers, for noiseless switching and noiseless potentiometers. Compression allows for the recording and transmission of signals with wide dynamic range. The analogue optocouplers can be set up to control the compression process. In high quality equipment, the threshold at which compression starts, the compression ratio and the level of “attack” and decay can all be controlled. It can also eliminate “breath effects” and remove any clicks when the volume is turned to zero.

Possible alternatives and their properties

The silicon photodiode is an obvious alternative to photoconductor, but has different spectral response and functions in a completely different way to photo-resistive cadmium sulphide and so its characteristics are not comparable and so it cannot be used as a drop in replacement.

An alternative type of sensor is an amorphous silicon photocell. These use amorphous silicon rather than single crystal silicon as in photodiodes. The spectral response is closer to that of the eye than for photodiodes. Although a better lighting match, it functions in the same way as other types of silicon photo-diode.

Although silicon devices may appear to show similar lighting response, a more important property for CdS opto-couplers is the range over which they operate and this is summarized in Table 1.

Table 1. Dynamic range of main photocell types

Photocell type	Dynamic range; light sensitivity for typical devices, actual vales depend on design but range is not significantly affected	Wavelength response
CsS/CdSe	0.02 Lux - >10,000 Lux	400 – 700 nm
Single crystal silicon	100 Lux – 1000 Lux	~400 – 1200 nm
Amorphous silicon (a-Is)	200 Lux – 600 Lux	<400 nm – ~820 nm
GaAs, GaAlAs	100 – 1000 Lux	~ 600 - ~950 nm

Apparent Alternative types of Analogue Optocouplers

There are several apparent alternatives to analogue optocouplers but all have significant disadvantages making them unsuitable for professional analogue audio applications. One option is normal optocouplers silicon semiconductor photodiodes or phototransistors, but all the unique features of the cadmium sulphide photo-resistor photoconductors will be lost and the performance of audio systems will be seriously degraded. Professional analogue audio uses AC and when this is used with silicon semiconductor opto-couplers, the shape of the AC signal is distorted which unacceptably alters the sound.

The only other way to control signals and isolate circuits is with a motor driven mechanical potentiometer. This would use considerably more materials, increase power consumption and have a short life due to wear of mechanical parts. All of these would have a negative impact on the environment.

As CdS opto-couplers use a passive device, the photoconductor, this has no distortion effect on sound, especially when not actively controlling the signal. Another apparent alternative would be a voltage controlled amplifier but this uses active devices and will introduce sound distortion.

Digital formats are increasingly used for non-professional applications such as for music compact discs but it is widely accepted that current digital technology does not reproduce music and sound perfectly, particularly at high and low frequencies. Although this is acceptable for audio equipment used by consumers, it is unacceptable for professional music recording, publishing and for concerts where the sound quality must be an order of magnitude better than non-professional equipment. The dynamic range of the human ear is very wide and it is not possible, using current digital techniques to accurately reproduce sound at very high and very low frequencies.

To replace all the unique features of the photoconductor by other electronic means might eventually be possible but it would increase the volume of electronics considerably and therefore ultimately the volume of electronic waste. Many manufacturers of professional audio equipment have been searching for alternative designs that do not utilize cadmium sulphide opto-couplers for several years but without success. It is feasible that alternative will become available after further research is carried out but no suitable substitutes have yet been found for the most demanding audio applications.

Comparison of cadmium sulphide with alternative semiconductor materials

Substitute photoconductors

Opto-couplers using cadmium sulphide are used mainly in professional audio equipment because of the high sound quality that can be obtained. These are not generally used in consumer products. There are several apparent substitutes but there are good technical reasons why all of these are unsuitable.

Many photoconductors exist but all have different characteristics. In opto-couplers, the sensitivity of the detector needs to match the light wavelength from the light emitting diode (LED) and so need not be sensitive to light that matches the human eye. LEDs are available with infrared, red, orange, green, blue and ultraviolet and there are photoconductor materials which match many of these. The LED can be chosen to emit a wide variety of light wavelengths from infrared to ultraviolet and this increases the number of semiconductors that are sensitive to LED light wavelengths. However the wavelength at which they respond is not the only essential criteria. However many of these alternative photoconductors contain either RoHS restricted substances (lead sulphide) or contain arsenic which is toxic and carcinogenic. The

electrical characteristics of the alternative photoconductors are quite different to cadmium sulphide as is described in section 5.1.

Manufacturers of photocells and opto-couplers have investigated alternative semiconductors but none have been found that meet all of the essential criteria provided by cadmium sulphide. For example, cadmium sulphide can be made with a relatively slow response time whereas most semiconductors respond to light levels very quickly. The change in resistance with light level and in particular the minimum resistance, the rate of change in resistance when exposed to light and when the light source is extinguished and the dynamic range are all also important properties that are not available except with CdS.

Main reasons for granting an exemption to the use of CdS

There are several unique features of CdS which cannot yet be replaced exactly or could only do achieved by the use of many additional optical or electronic components, some of which with contain other hazardous substances and this approaches would add considerably to the ultimate level of electronic waste. Silonex estimate that only about 1kg of Cd is used each year in CdS photocells and CdS opto-couplers which are used in products that are within the scope of the RoHS directive.

One manufacturer of cadmium sulphide photocells has claimed that their products are RoHS compliant however an example has been analyzed by an independent laboratory in UK and these contain a layer of cadmium photo-resistor and so cannot be used in RoHS compliant products unless an exemption is granted. The manufacturer's claim is probably based on the analysis of a sub-part of the component and not of individual homogeneous materials.

Suggested definition of new exemption:

Cadmium in analogue cadmium sulphide/selenide optocouplers for professional audio frequency control and monitoring, and for signal processing applications.

Respectfully submitted,



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