LIGO Laboratory / LIGO Scientific Collaboration

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Satellite Box Design Description

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http://www.ligo.caltech.edu/

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http://www.sr.bham.ac.uk/research/gravity/rh,d,2.html
http://www.eng-external.rl.ac.uk/advligo/papers_public/ALUK_Homepage.htm

SATELLITE BOX DESIGN DESCRIPTION

CONTENTS

1, INTRODUCTION

This document describes the design of the Satellite Box Electronics Unit for Advanced LIGO.

1.1 Context

The Satellite Boxes provides current sources for the OSEM LEDs, and processes the output currents from the OSEM photodiodes. This provides the position detector part of the suspension control system.

Monitoring circuits are also included in the satellite box, to monitor its activity.

2. The Suspension Control System

The Satellite Box forms part of the control system which controls the position and movement the suspension stages electromagnetically. Fig 1 is a simplified diagram of the control system, illustrating the role of the Satellite box.
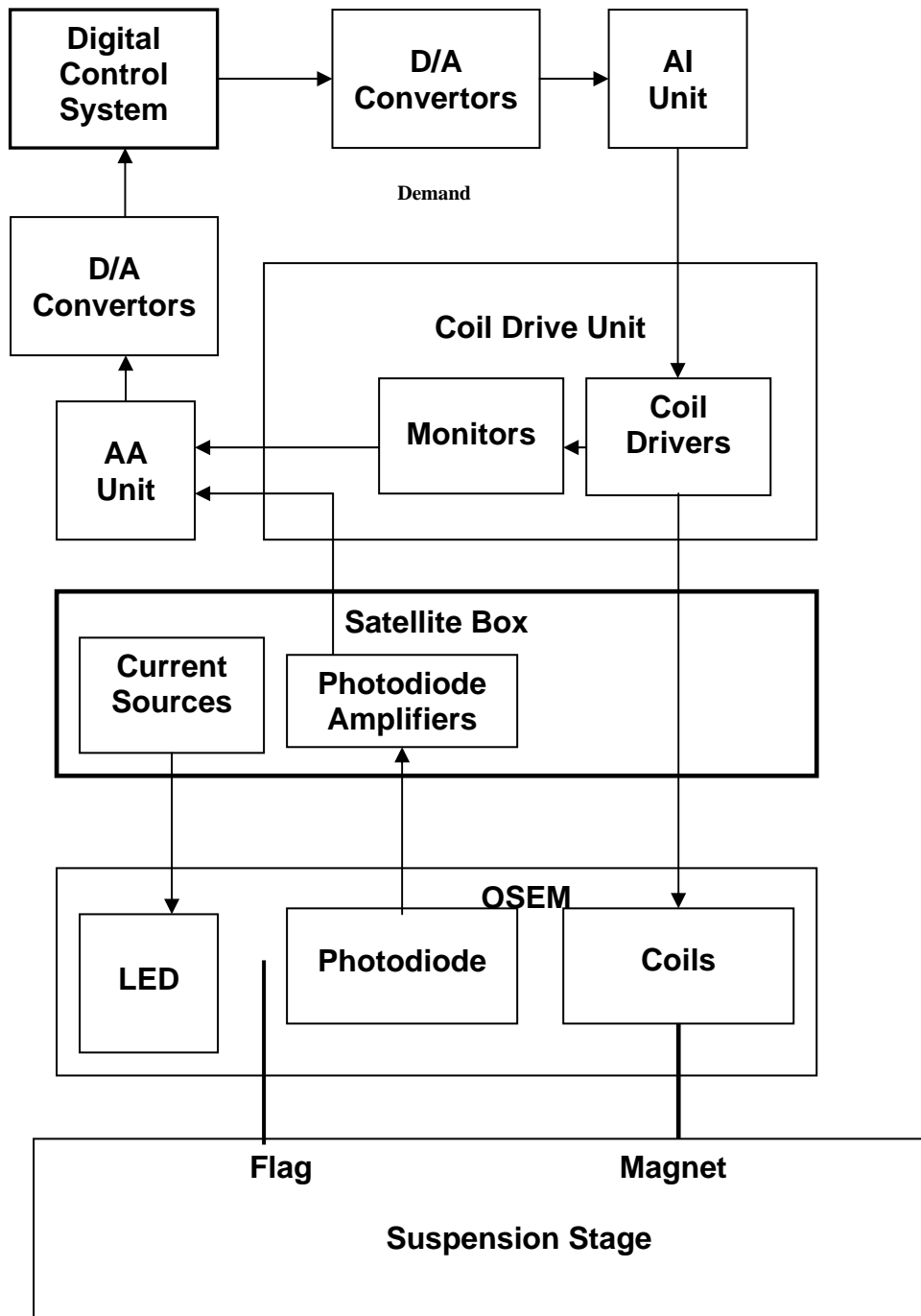
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┌──────────┐        ┌──────────┐      ┌────────┐
│ Digital  │───────▶│   D/A    │─────▶│   AI   │
│ Control  │        │Convertors│      │  Unit  │
│ System   │        └──────────┘      └────────┘
└──────────┘          Demand
     ▲
┌──────────┐
│   D/A    │        ┌─────────────────────────────────┐
│Convertors│        │        Coil Drive Unit          │
└──────────┘        │                                 │
     ▲              │  ┌──────────┐   ┌──────────┐    │
┌──────────┐        │  │ Monitors │──▶│   Coil   │    │
│   AA     │◀───────┼──│          │   │  Drivers │    │
│   Unit   │◀───────┼──└──────────┘   └──────────┘    │
└──────────┘        └─────────────────────────────────┘

┌─────────────────────────────────────────────────┐
│                 Satellite Box                    │
│  ┌──────────┐   ┌──────────────┐                 │
│  │ Current  │   │  Photodiode  │                 │
│  │ Sources  │   │  Amplifiers  │                 │
│  └──────────┘   └──────────────┘                 │
└─────────────────────────────────────────────────┘

┌─────────────────────────────────────────────────┐
│                      OSEM                        │
│  ┌──────┐   ┌──────────────┐   ┌──────────┐      │
│  │ LED  │   │  Photodiode  │   │  Coils   │      │
│  └──────┘   └──────────────┘   └──────────┘      │
└─────────────────────────────────────────────────┘

┌─────────────────────────────────────────────────┐
│   Flag                      Magnet               │
│              Suspension Stage                    │
└─────────────────────────────────────────────────┘
```

Fig 1 The Control System

The Demand signal, processed by the Coil Drive Unit, requests a selected suspension movement, energising the coil which attracts the magnet on the

suspension stage, moving the suspension. The position of the suspension stage is detected by the means of the LED and photodiode pair in the OSEM position detectors, providing position feedback to the control system.

The OSEM works as follows: The focussed light beam from the LED in the OSEM is partially interrupted by a mechanical flag mounted on the suspension. This partly obscures the light falling on the photodiode, resulting in an analogue output from the photodiode which is dependant on the flag position, and hence the suspension stage position.

The main function of the satellite box is to generate a stable, low noise LED current, and to amplify and filter the output from the OSEM photodiodes.

There are four channels of current sources and amplifiers in each satellite box.

3. The Satellite Box

```
┌──────────────────────────────────────┐
│                                        │
│   ┌─────────────────────┐              │─────►  LED Current
│   │                     │              │
│   │   CURRENT SOURCE    │              │─────►  Monitors
│   │                     │              │
│   └──────────┬──────────┘              │
│              │                         │
│              ▼                         │
│   ┌─────────────────────┐              │
│   │                     │              │─────►  Indicators
│   │   WINDOW DETECTOR    │             │
│   │                     │              │
│   └─────────────────────┘              │
│                                        │
│   ┌─────────────────────┐              │
│   │                     │              │─────►  Output
│   │    PHOTO DIODE       │             │
│   │                     │              │
│   │    AMPLIFIER         │             │
│   │                     │              │─────►  Monitors
│   └─────────────────────┘              │
│                                        │
└──────────────────────────────────────┘
```
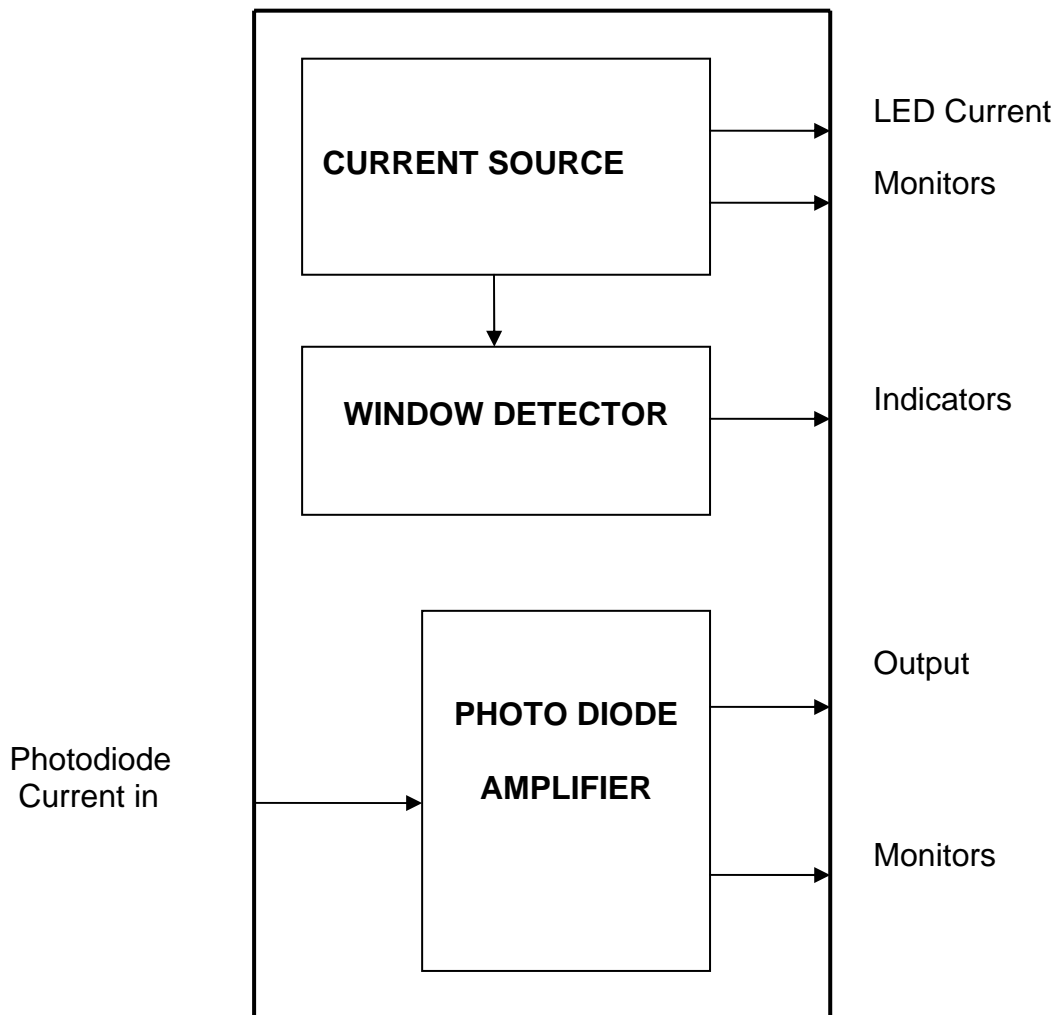
Photodiode Current in

Fig 2 Satellite Box Block diagram

The Satellite Box contains three main functional blocks:
1. The Current Source
2. The Photodiode Amplifier
3. The Window Detector
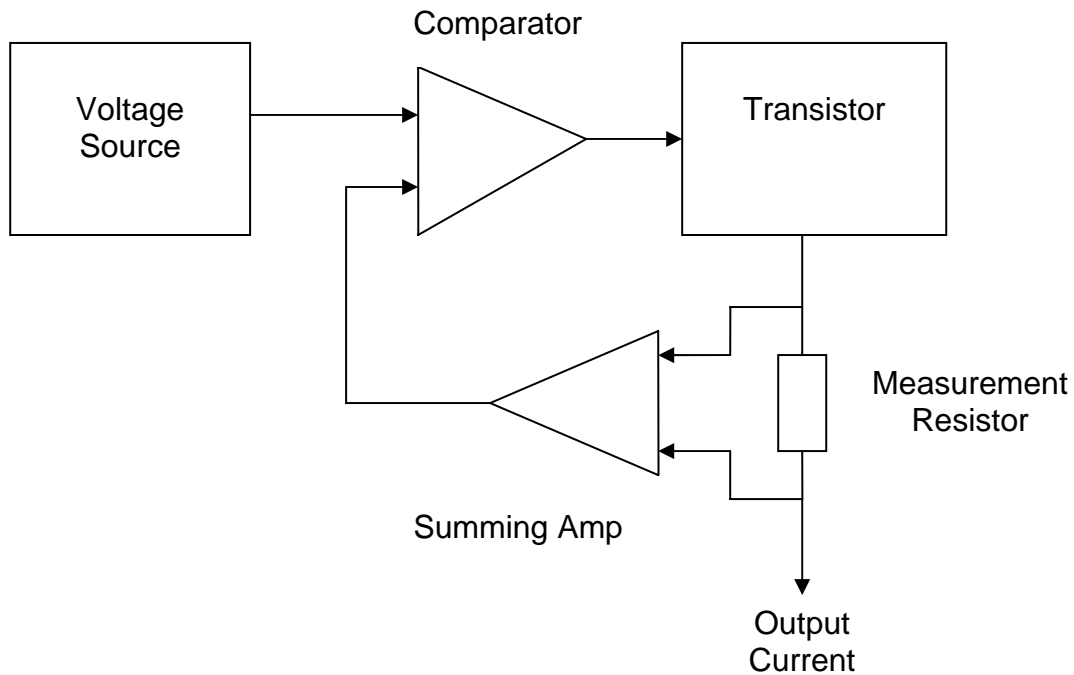
3.1 The Current Source

Fig 3 Block diagram of the Current Source

The current source functions as a feedback circuit. A precision voltage source provides a low noise, 1v stable reference the system.

This reference is derived from an ADR421 precision 2.5 volt reference by means of a potential divider consisting of extremely precise, low noise resistors. Filter capacitors are included to reduce the noise level further.

The output current passes through a precision, stable, low noise resistor. The voltage across this resistor is compared with 1volt reference signal, and the result of this comparison is used to adjust the output current appropriately by means of a transistor circuit.

3.2 The Photodiode Amplifier
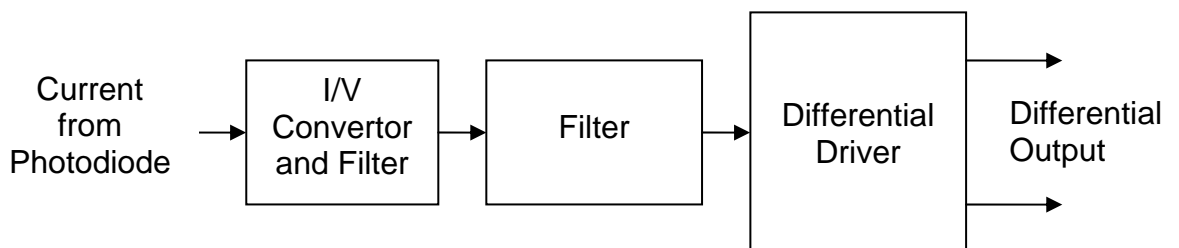
Fig 4 Block diagram of the Photodiode Amplifier

3.2.1 Current to Voltage Converter

The first block is a current to voltage converter. The current from each photodiode, which has a nominal full scale value of 60µA, is converted into a voltage by means of an operational amplifier current to voltage converter, with a transfer function of 0.16 volts per microampere. Its frequency response is defined by a 220pF capacitor shunting the 160K feedback resistor, giving it a low pass characteristic with a corner frequency of 4.5 KHz.

3.2.2 "Whitening" Filter

This is followed by a "whitening" filter, which emphasises the frequencies of interest. At low frequencies it has unity gain. The circuit is a high pass filter with a corner frequency is 4 Hz. Above 10 Hz the gain levels off to a gain of 3.7.

3.2.3 Differential Driver

The output driver is a differential Driver stage with unity gain, giving a balanced drive signal to the A/D converters, with 10v peak drive in each output. The drivers incorporate a low pass filter with a corner frequency of 50 KHz.
Two additional outputs provide monitor signals, scaled in the same way.

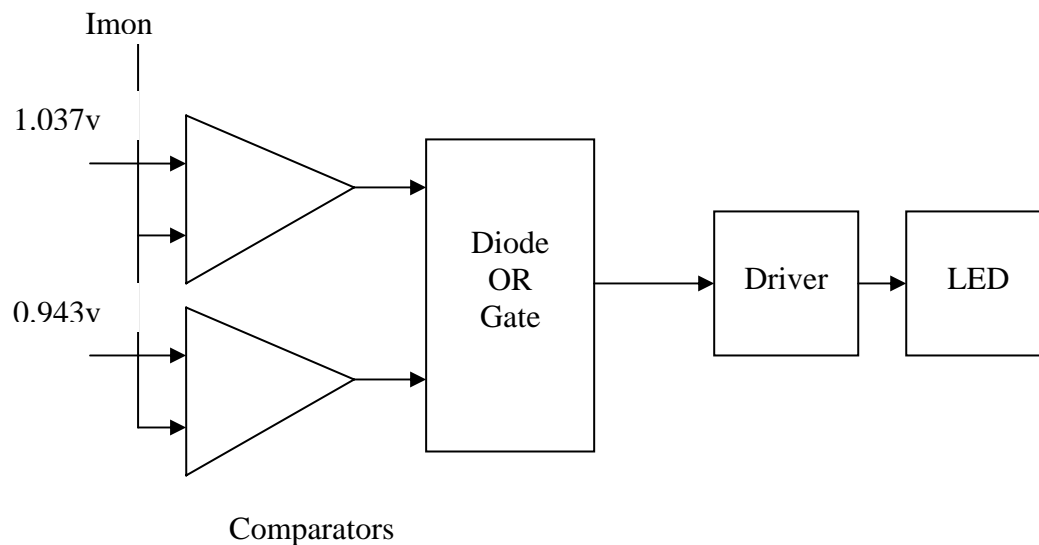### 3. The Window Detector

Fig 5 Block diagram of the Window Detector

The window detector acts as a fault indicator. It monitors the voltage across the measurement resistor, and detects if it deviated from 1.000 volts by more than a small amount. If the voltage exceeds 1.037v, or is below 0.934 volts the fault LED becomes illuminated.

The comparators check the voltage levels. If either comparator output becomes high, a diode in the diode OR gate will conduct, causing the drive

transistor to conduct, illuminating the LED. Each comparator is furnished with positive feedback, to prevent jitter. When the power is turned on, the LED becomes illuminated briefly, checking the circuit.

3.4 LIGO1 OSEM Photodiode bias

The Satellite box may be used either with Birmingham OSEMs or with LIGO 1 OSEMs.

The most important difference between the two types of OSEM is that the LIGO1 OSEM requires the photodiodes to be reverse biased. This is achieved by inverting, filtering and buffering the reference voltage, to give a negative reference voltage. The bias voltage is selected by means of a link when LIGO 1 OSEMs are being used.

3.5 Power Supplies

The power supplies required for the Satellite box are generated by on board regulators, which derive the required +14v, -14v and +5v supplies from the raw power supplies. LED monitors are included, to indicate that the each of the internal power rails is present.