A Cloud Detector for Automated Telescopes

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Abstract: An instrument is described that can detect clouds at night-time by sensing their infrared emission. The device can readily detect clouds that are difficult to see with the unaided eye on a moon-lit night. It can be used to provide an indication of how photometric the conditions are, to terminate exposures when cloud forms, and to close the dome when conditions become unsuitable for observing. The detector also has applications as an astronomical site-surveying instrument.

1. Introduction

When making ground-based optical observations it is crucial to know the extent of cloud cover. Normally this is done visually by the astronomer, who then annotates the affected observations. However, for a telescope designed to be run remotely under computer control without an astronomer present, such as the Automated Patrol Telescope run by the University of New South Wales at Siding Spring Observatory, a different approach is necessary. It is with this problem in mind that we have developed a microprocessor-controlled cloud detector.

2. The Detector

Clouds can be detected by radar and laser reflection, through the effect they have on attenuating light from a star, or through the infrared emission from the clouds themselves (see Sloan *et al.* 1955 for a discussion of the infrared emission spectrum of the sky). We use this last method and employ an inexpensive single-element infrared detector based on the pyroelectric effect. Such detectors are commonly available as the sensors for infrared intruder alarms and have a broad spectral response from 1 μm to beyond 15 μm, although often modified by the transmission of a window.

The pyroelectric effect is a property of ferroelectric materials such as triglysine sulphate that show a large spontaneous electrical polarization below their Curie temperatures. The polarization varies with the temperature of the material, and hence is affected by the incident radiation. In practice, the ferroelectric crystal forms a capacitor which biases the gate of a field-effect transistor (see the dashed box at the top left of Figure 1).

The signal from a pyroelectric detector responds within a few milliseconds to changes in the impinging infrared radiation. However, the signal returns to its DC level with a time-scale of $\sim$ 1 s due to the high-pass filter formed by the ferroelectric crystal and the parallel resistance Z_g. Therefore, in order to detect the absolute value of the infrared emission from an object it is necessary to chop between the object and a reference source at frequencies $\gtrsim$ 10 Hz. In our design the reference source is the thermal radiation from an aluminium-bladed chopper, coated matt-black to reduce reflection.

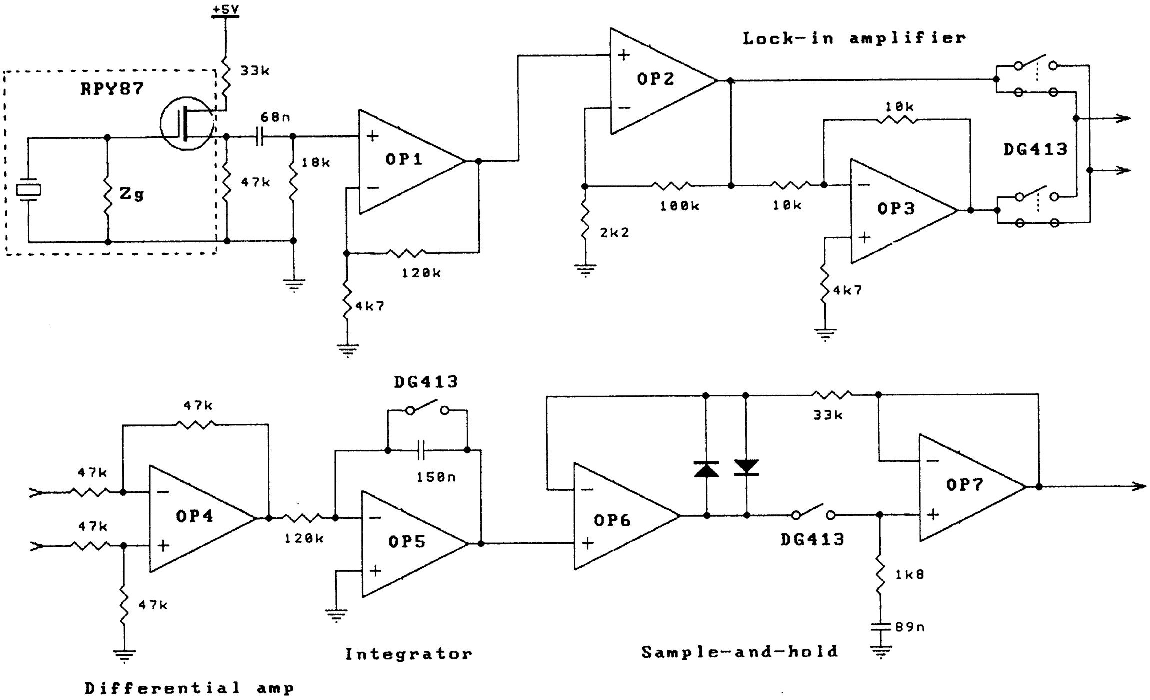

Figure 1 – Schematic diagram of the analogue electronics for the cloud detector. The op-amps are all OP490's or equivalent.

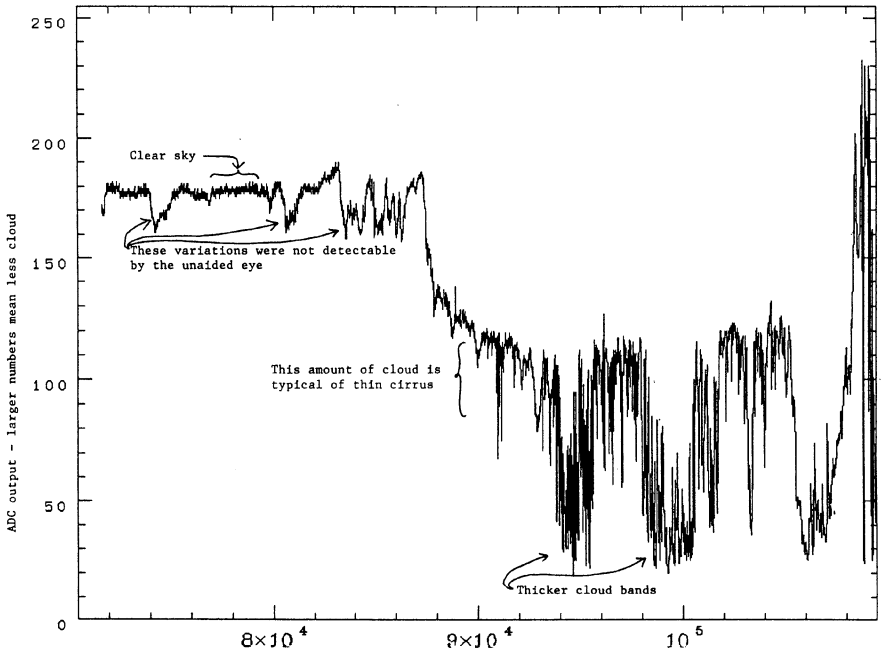

Figure 2 – A night's observations with the cloud detector. The horizontal axis is the number of seconds since 0 hrs local time.

3. The Mechanical Design

The pyroelectric detector used was a Phillips RPY87 and comes in a standard TO-5 package. A number of other manufacturers offer suitable detectors, although it is important to obtain a *single-element* detector, not the dual and quad detectors that are designed for detecting changes in an infrared scene imaged onto them. The individual elements in these latter detectors are connected in anti-parallel, and so do not respond to the total incident flux.

The detector is mounted at the focus of a 50 mm diameter f/2 mirror (conveniently obtained from a Kodak slide projector). The mirror increases the sensitivity of the detector and also sets the field of view to ~ 15°. Incoming radiation is interrupted by a rotating chopper at a frequency of 25 Hz. Both the mirror and chopper mechanism are attached to a small altazimuth mounting driven by two stepper motors. The motors are controlled using an IBM-PC compatible computer through a simple RS-232 interface, allowing complete flexibility of positioning and the ability to scan areas of sky.

An alternative method of mounting the cloud detector is to simply fix it to the tube of an existing telescope. Although this relinquishes the ability to map the sky in regions other than where the main telescope is looking, for many purposes this will be adequate, and should provide sufficient warning of incoming cloud.

4. The Electronics

A schematic diagram of the electronics used with the detector is shown in Figure 1. The signal from the detector passes through a high-pass filter ($\tau = 0.1$ s) to remove the DC component prior to amplification by a factor of 25 by OP1. This op-amp is mounted directly behind the detector to minimise noise pick-up. The signal is amplified by an additional factor of 45 by OP2, and then inverted by OP3. The outputs of OP2 and OP3 pass through an analog switch sychronised to the chopper frequency, and then to OP4, a differential amplifier. OP2, OP3, and OP4 form a simple lock-in amplifier. The signal is integrated by OP5 over two chopping cycles and is captured by the sample-and-hold circuit comprised of OP6 and OP7. The output of OP7 passes through an additional level shifting and amplification stage (not shown) in order to scale the output prior to reaching an 8-bit analog-to-digital converter. The ADC is read using the same RS-232 interface that controls the stepper motors.

We have also developed a battery-powered microprocessor controller for the cloud detector that is capable of recording cloud measurements at a fixed position in the sky every minute for a year. This device has applications as a site selection/monitoring instrument.

5. Results

Figure 2 shows the result of 12 hours of cloud monitoring, with measurements made every second. The first half of the night appeared quite clear to the unaided eye. During the second half, bands of cirrus cloud moved in, and these were easily detected by the instrument.

6. Future Improvements

A problem with the pyroelectric detector we used is that its response extends just below 1 μm, making it unsatisfactory on moon-lit nights or during twilight. This could be easily remedied by the use of an appropriate filter. An additional problem is that the reference signal (the chopper blade) varies with ambient temperature. This could be corrected for by measuring the temperature, or alternatively, a temperature-controlled black-body source could be used.

Acknowledgements

An earlier version of the cloud detector was developed at UNSW by John Storey and has been worked on by two Honours students: K. Meaney and M. Hardy. The original idea of building a cloud detector along these lines came from discussions with Patrick Roche.

Sloan, R., Shaw, J. H., and Williams, D., 1955, *J. Opt. Soc. Amer.*, **45**, 455.