

# SYSTEM DESIGN NOTE

## NFM-AD-02-5101 Temperature stability of array control electronics

<u>Prepared by</u>	<u>Date</u>	<u>Approved by</u>	<u>Date</u>	<u>Rev.</u>	<u>Rev. Date</u>
Ron Probst	1/28/04				

### 1. Introduction

This SDN derives requirements for the signal processing stability of the NEWFIRM array control electronics (nominally the MONSOON controller) in the presence of temperature variations. Such variations would presumably arise due to coupling to the variable temperature dome and Cass cage environment, as cooling air is extracted from the Cass cage and circulated through the electronics.

This is distinct from the amount of heat permitted to be dissipated in the cage. That is treated in SDN 1105 Heat Removal from Cass Cage.

In Section 2 I summarize the requirements and in Section 3 I derive them. Section 4 has a few remarks on MONSOON design and performance vis-à-vis these requirements.

### 2. Basic Design Requirements

The three system properties of the electronics signal chain that are important for signal integrity and might be temperature dependent are the offset or bias level, system gain, and system linearity. Drifts matter on different timescales, discussed in Sec. 3. The design requirements for immunity from change with temperature are

2.1 The electronic signal offset (bias level) shall change by no more than 0.5 ADU (2.5 electrons) per degree C.

2.2 The system gain (electrons per ADU) shall change by no more than 1 part in 15000 per degree C.

2.3 The system linearity shall degrade by no more than 1 part in 15000 per degree C.

### 3. Derivation of requirements

Offset variation has an additive effect. Deriving the requirement requires assuming some numbers about input flux, array performance, and the controller plus a knowledge of the environmental temperature change on the relevant timescale. Gain and linearity correction are multiplicative, so the derivation is merely a question of the parts-per-X accuracy desired and the temperature change.

#### 3.1 Offset variation

The relevant time scale is the longest integration time interval between the two array reads of a correlated double sample. A bias drift within this period will not be corrected when the two reads are differenced. The longest integrations will be associated with the lowest input flux, e.g. a narrow filter in the short wavelength part of the system response. Note I am not assuming any benefit from bias monitoring pixels on the array.

From the Operational Concepts Definition Document, we have the lowest expected flux is about 30 electrons per pixel per second, for a 1.5% filter in the J window. Assume a system read noise of 20 electrons rms. Then a background limited observation, defined as Poisson noise of sky flux = 3 times the read noise, requires 120 seconds. In practice longer integrations, up to 300 seconds, are typically taken under such low flux conditions for reasons of overall efficiency. In 300 seconds on the sky we obtain

$$\text{Signal per pixel} = 30 \text{ e-}/\text{sec} \times 300 \text{ sec} = 9000 \text{ e-}$$

$$\text{Poisson noise per pixel} = \sqrt{9000} = 95 \text{ e-}$$

So the photometric precision imposed by Poisson statistics is about 1%. We want systematic effects from the electronics to be well below this; I arbitrarily set the level at 0.1% or 1 part in 1000. Then the allowed offset drift over this 5 minute interval is 9 electrons.

Since we are talking about drift due to temperature change, how large is this over 5 minutes? The electronics will respond to changes in the ambient air temperature since this is what is being drawn into the enclosure to cool them. In my examination of several months' worth of KPNO 4-m temperature logs, the largest temperature change for Cass cage air temperature recorded in 5 minutes while observing was 2.5 °C. Typical values are much less.

The allowed drift is then  $9 \text{ e-} / 2.5 \text{ °C} = 3.6 \text{ e-}$ .

Electronics system characterization will be conducted using ADU's, not electrons, as the unit. Assuming a gain of about 5 e- / ADU, the allowed drift is 0.7 ADU per °C. For the requirement I have derated this further to 0.5 ADU or 2.5 electrons per °C. Note the fundamental requirement is expressed in electrons, not ADU's.

### 3.2 Gain variation

Gain is multiplicative. Again we want any effect of gain drift to be well below the precision set by the external flux. Typically this is 1% photometric precision for carefully calibrated infrared photometry. I shall arbitrarily set the requirement for gain drift as 0.001 or 1 part in 1000.

There are several applicable time scales. We don't want the gain drifting during the course of a night's observations, so the data can be calibrated by observations of standards. So this is a timescale of hours. System gain determination usually uses data gathered in the daytime, and not every day; a timescale of at least tens of hours. In fact gain measurements may be as infrequent as once or twice a year, timescales of hundreds to thousands of hours. They may also be taken during warm weather in mid-afternoon and applied to data taken at night during cold weather.

The largest Cass cage temperature variations measured on these timescales are about 15 °C. The allowed temperature dependent drift in the system gain is then 1 part in 15000 per °C.

### 3.3 Linearity variation

This enters in when scaling bright standard stars to derive the magnitudes of much fainter objects. The discussion and resulting requirement are the same as for gain variation.

## 4. Discussion

These requirements apply only to electronics variation in the presence of temperature changes. Some of the time scales are quite long (months) and the electronics are assumed to be stable against other forms of degradation over such periods. Certainly gain and linearity will be measured repeatedly during instrument commissioning on the telescope to establish that they are stable over long periods.

In terms of expected MONSOON performance, these requirements are not demanding<sup>1</sup>. Offset variations are most likely to arise in resistors and op-amps; gain variations, in these and to a lesser extent capacitors and A/D converters; and linearity degradation arises in the A/D converters. All components are being procured to tight tolerances, typically 25 parts in 10<sup>6</sup> for temperature sensitivity. This gives a safety factor of several below my gain and linearity requirements. Bias drift is being held to an order of magnitude or better less than my specification so that MONSOON will be suitable for spectroscopic applications. This science typically has significantly lower source fluxes and much longer integration times than NEWFIRM imaging science.

---

<sup>1</sup> I thank Mark Hunten for this discussion.