Fast microbolometer-based infrared camera system

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Until now microbolometer-based cameras have been operated only at 50/60 Hz. Since microbolometers are now available with faster read out integrated circuits (ROIC) and with a low thermal time constant of the microbolometer pixel, they are getting more and more interesting for high speed applications. In this paper, a fast high-performance IR camera equipped with a state-of-the-art microbolometer focal plane array is presented.

The newly developed camera system is based on a long-wave infrared range (LWIR) microbolometer camera system with 384 × 288 pixels. The camera operates at 100 Hz. The camera system consists of a camera head and a PC frame grabber plug-in board with CameraLink interface.

The camera system is suitable for stationary use in harsh industrial environments. The robust housing can be completed by integrated water-cooling and air purge for the lens system. The camera is equipped with trigger inputs for the synchronization with the process to be measured.

The high resolution and sensitivity values of the presented IR camera allow its use for sophisticated temperature measurement tasks. The IR camera is especially suited for long-time process monitoring or quality control in industrial facilities.

1 Introduction

So far microbolometer focal plane arrays (FPA) are being used only with a frame rate of 50 Hz. The maximum frame rate depends on the thermal time constant of the microbolometer pixel, the speed of the read-out integrated circuit (ROIC) and the read-out mode. In chapter 2 these limits are described. It is shown that microbolometers on the basis of amorphous silicon are usable for a radiometric infrared camera system with a frame rate of 100 Hz. Subsequently such a system is presented in chapter 3.

2 Time limits of a microbolometer

2.1 Thermal time constant

The thermal time constant τ_{th} of a bolometer is determined by the thermal mass C and by the thermal conductance G between the pixel and its enviroment:

$$\tau_{th} = \frac{C}{G} \quad . \tag{1}$$

It depends on the bolometer construction and the resistor material used. Typical values for commercial microbolometers are given in table 1.

Material	Time constant in ms	Response time in ms
Vanadium oxide VO_X	15	45
Amorphous silicon a:Si	7	21

Table 1: Typical values for thermal time constants [1], [2]

The frequency dependence of the responsivity $R(\omega)$ of a bolometer can simply be expressed by /3/:

$$\frac{R(\omega)}{R_0} = \frac{1}{\sqrt{1+\omega^2\tau_{\mathrm{th}}^2}} \tag{2}$$

where R_0 is the DC responsivity. That means that the output voltage $U(t)$ of a pixel follows an input step exponentially:

$$\frac{U(t)}{U(t\to\infty)} = 1-e^{-\frac{t}{\tau_{\mathrm{th}}}} \tag{3}$$

Figure 1 shows the output signal after an input step. After a time > $3\tau_{\mathrm{th}}$ the output becomes 95 % of its final value. This time is usually called response time (see table 1). The response time is the minimum time to be waited for after the object temperature is changed. After $t > 6\tau_{\mathrm{th}}$ 99 % of the final value are reached.

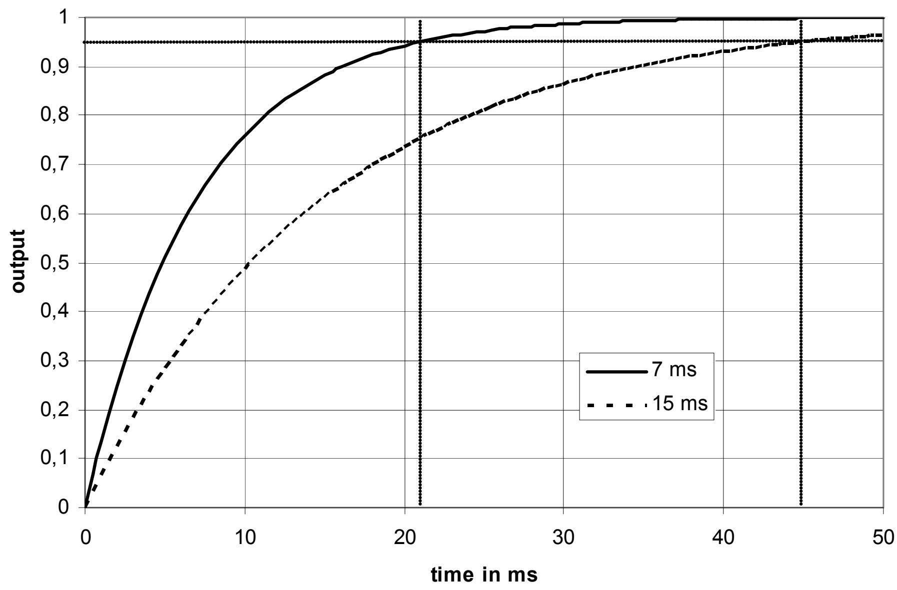

Figure 1: Output signal after an input step (Parameter: time constant τ_{th})

2.2 Frame rate

The maximum of the frame rate is specified by the ROIC. Usually, the analog output amplifier of the ROIC gives the maximum of the pixel frequency. Typical pixel frequencies for different frame rates and usable focal plane array sizes are given in table 2. Practically, the pixel frequencies are slightly higher due to extra clocks for the ROIC. For large FPAs, two analog outputs are usable.

	Frame rate		
Size	50 Hz	100 Hz	200 Hz
320 × 240	3.84 MHz	7.68 MHz	15.36 MHz
384 × 288	5.53 MHz	11.1 MHz	22.1 MHz
640 × 480	15.36 MHz	30.72 MHz	61.44 MHz

Table 2: Pixel frequency

The frame rate is the sampling rate of the scene. A signal must be sampled at a rate greater then twice its maximum frequency in order to ensure unambiguous data (Nyquist's criterion). So the maximum permissible scene frequency is the half of the frame rate. For example, the maximum scene frequency of an a:Si-bolometer and 100 Hz frame rate is 50 Hz. That corresponds to a cycle duration of 20 ms. This value is in good agreement with the response time of an a:Si-bolometer (see 2.1).

2.3 Read-out mode

The read-out of the pixels is organized row by row (Fig. 2). Therefore, the object will be sampled one row after another. By this read-out procedure, the object appears chopped if it is moving, since every following row is shifted to the preceding one. The maximum shift and hence the maximum object speed is limited by the measurement task.

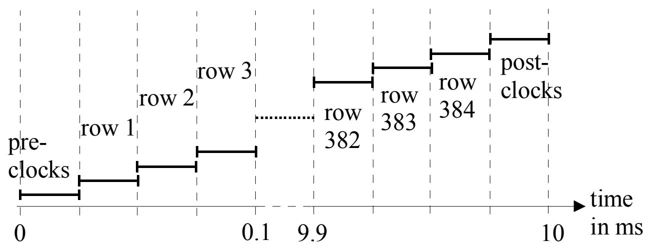

Figure 2: Read out row by row (1 frame, 384 rows, 100 Hz frame rate)

3 Camera design

The intention of this work was to develop a fast high-performance uncooled infrared camera for non-contact temperature measurement. The camera design was based on universal electronic components, which can be adapted inexpensively to different sensor types and various industrial applications /4/. The camera system was developed primarily for the use with microbolometer arrays. Figure 3 shows the overall system set-up.

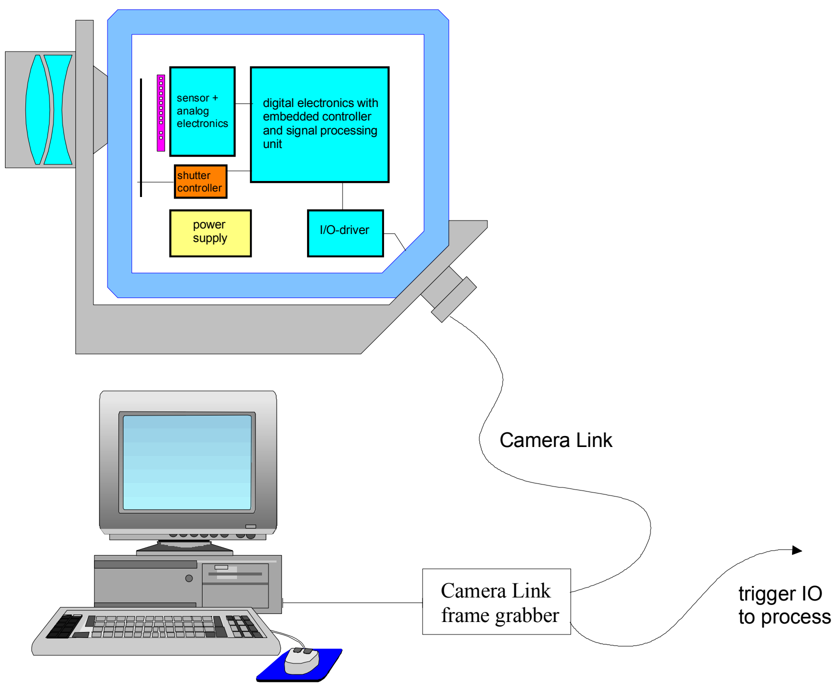

Figure 3: Set-up of the camera system

For internal signal corrections, a shutter is used. The shutter cycle is given by temperature changes of the optical channel. The shutter can be synchronized to an external process.

Figure 4: Camera head

The camera system is designed for stationary use in harsh industrial environments. The robust housing (Fig. 4) may be completed by an air purge for the lens system and an integrated water-cooling. The camera system is equipped with trigger inputs to synchronize the camera system to an industrial process. For visualization, a computer is used. The camera system is connected with a computer via a standard interface (CameraLink). Table 3 shows the performance data of the camera system.

Spectral band	8 µm to 14 µm
Measured temperature range	–20 °C to 500 °C (two ranges)
Detector	384 × 288 pixel uncooled bolometer
NETD	< 120 mK (30 °C)
Field of view	30°× 23°
Frame rate	100 Hz
Camera operating temperature range	0 °C to 50 °C

Table 3: Selected technical data of the camera system

4 References

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