CCD Camera for Amateur Astronomy

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Although the Z8*Plus* microcontroller family was designed for simple peripherals such as a mouse or joystick, its features and level of integration make it well suited to many other real-world applications. This example, a CCD camera designed for astronomical imaging, provides an effective demonstration of the Z8's capabilities. Fig. 1 is a block diagram of the circuitry.

The heart of the camera is a Z8E520 with integral Universal Serial Bus. Both power and interface to a host PC are supplied by the USB. Current draw is a mere 15mA (30mA during readout). The 640 x 480 pixel CCD array from Texas Instruments is a popular choice for electronic astrophotography. Long exposure times (measured in minutes) permit slow readout allowing the Z8's I/O pins to directly control the various CCD clocks. This achieves great flexibility in pixel binning and image cropping – creating essentially a "software" camera. MOSFET drivers are used to buffer the Z8 outputs to appropriate bias levels required by the CCD.

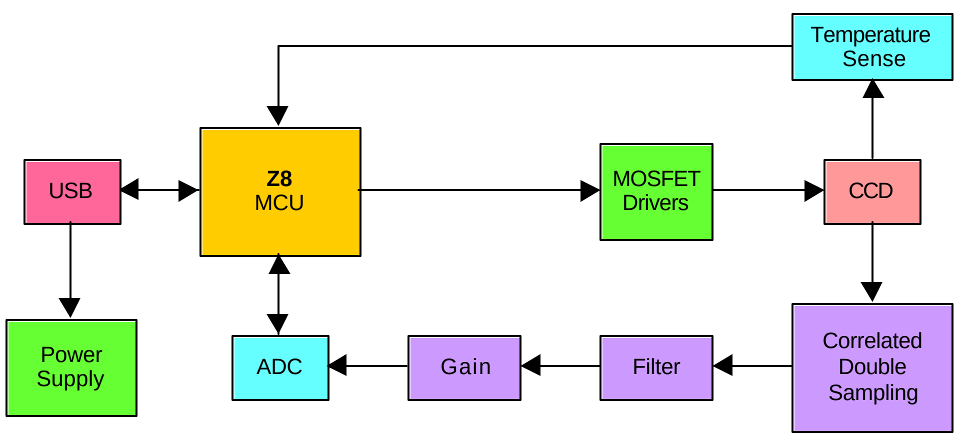

Figure 1. Block diagram of CCD camera.

The Z8 interacts well with analog circuits given its flexible I/O. An inverted-mode correlated double sampling (CDS) front end uses pin 9 configured as an open-drain FET analog switch. With the FET on, C13 samples the output voltage of a pixel. Turning the FET off during the following reset phase presents a positive voltage to the input of U7B that is proportional to the number of photons collected. This inverted technique accommodates the single supply opamp gain stages by preventing negative signals.

The low pass Bessel filter removes high frequency noise from the signal. A Maxim 12 bit ADC samples the signal under control of a 3-wire serial interface synthesized in Z8 firmware. This balance between hardware and software reduces cost by eliminating the need for additional circuitry. Once received, data are immediately sent out the USB port obviating the need for local memory. At 50ksps it takes about seven seconds to read out an entire frame.

A variable anti-blooming control is created using the programmable current sink feature provided by pin 2. Level shifting above the Z8's supply voltage is accomplished by the cascode connection of Q1. This configuration provides an adjustable 13V to 22V bias supply in 1V increments.

The CCD must be cooled below 0°C to minimize dark current errors (cooling supply not shown). A closed-loop feedback system is implemented using a digital PID filter in firmware and applying timer T01 as a PWM. The analog comparator feature of pin 4 and a thermistor are employed to create a novel temperature-to-digital converter, see Fig. 2. Initially, the port is actively driven high to charge up C7. Later, configured as an input, its voltage discharges exponentially with a time constant τ equal to R2 times C7. By selecting voltage reference VR2 (36% or 1/*e*) t is measured directly by timer T23.

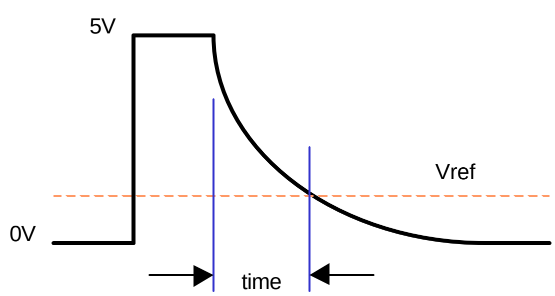

Figure 2. Temperature-to-digital conversion cycle.

Even though the resistance vs. temperature characteristic of the NTC thermistor is dramatically non-linear, +/-2C accuracy is achieved in firmware by applying the formula

$$Temperature = 107 \cdot (t)^{(-0.12112)} - 163$$

where t is given in seconds.

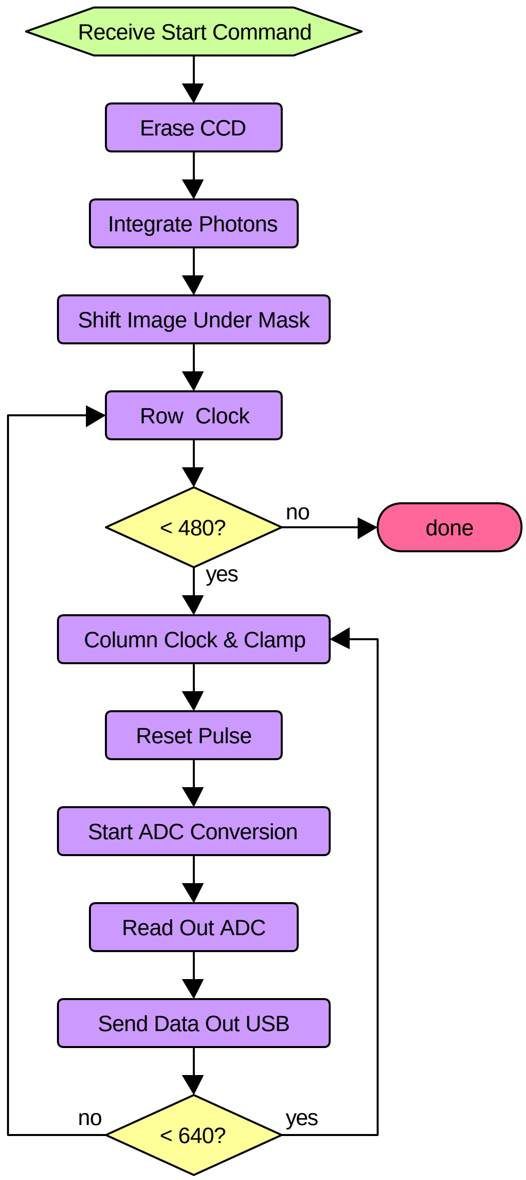

Figure 3. Simplified flowchart of an exposure.