Inter-Office Memorandum

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This memo discusses the issues involved in using a MARIT detector array with the Jasmine opto-mechanical package to produce a low cost high resolution 4-color scanner (Star Jasmine), and with new optics and transport to produce a scanner for 35mm slides (Mimosa). The main advantage of higher resolution is the ability to zoom in on a small portion of a document or image; current facilities preclude storing over 13Mbytes per color, or over 55Mbytes per 4-color page. "Star Jasmine" is the name of a plant which is not a Jasmine at all.

MARIT

MARIT is a CCD detector array developed by Bob Sprague (OSL). It has four channels of video; with appropriate color filters these channels provide red, green, blue, and monochrome signals. Each channel is implemented with 8 rows of 1030 CCD elements. When a photon hits a CCD element, charge is generated. In order to provide a high resolution array (4120 elements), the top four rows are covered by a *staggered aperture mask*, and the bottom four rows are completely shielded from light. The staggered aperture mask covers 3/4 of each CCD element, so that the first row contains pixels 0,4,8,...,4116 of one scan line, the second row contains pixels 1,5,9,...,4117 of the next scan line, and so on.

Three clocking signals are used to control the chip. The *scan* clock shifts the top four rows down one row; the *shift* clock shifts the bottom four rows down; the *data* clock shifts the bottom row to the right, ouputting the charge stored on the rightmost element. Note that shifting into the bottom row causes charge to be added to the charge already stored there. The bottom row is cleared by 1030 (or more) data clocks.

In order to permit high speed operation, the aperture masks are rectangular and designed to operate with anamorphic optics which distend the image 4:1 vertically. Four times more light is incident on each element using this scheme.

Jasmine

Jasmine uses a 1024 element Reticon detector array, implemented with photodiodes and capacitors. The source document is held in a TC200 paper transport and illuminated by an array of tungsten lamps. The optics focus each inch of the document onto 96 detector elements, and a stepper motor moves the document 96 steps/inch. The digital interface provides 8 bits per sample, and will deliver lower resolution scan lines by undersampling the array.

Star Jasmine Mechanical Modifications

Hardware modifications may be required to the optics, the MARIT array, the light source, and the stepper motor.

MARIT's requirement for anamorphic optics is a problem not only because of high cost, but also because the short optical path used in Jasmine will not accomodate cylindrical lens elements. Redesigning the optical path will have many ramifications for packaging. Instead, we can provide 96 samples/inch in color with undersampling, time delayed integration, or by removing the aperture mask. Using the standard mask, it would be possible to provide 384 samples/inch across 96 scanlines/inch. We can also use a square aperture mask to yield 384 samples/inch in color; the digital interface will provide samples at a maximum rate 250 kHz, which allows enough integration time for the smaller aperture. The stepper motor would need to be geared down 4:1 for 384 scanlines/inch. The light source may need to be modified for color, to provide more even power across the visible spectrum.

The current proposal is to build a prototype unit with unmodified Jasmine optics, and using an unmodified MARIT array. At a later time, we will convert to a square aperture mask on the array and a geared down paper transport. Experimentation with various light sources will be possible using either the Reticon array with color filters, or a MARIT array.

Mimosa Requirements

A great advantage of working with color slides is the increased dynamic range available with a transmissive light path through film. Gary Starkweather (OSL) is designing a new transport in which the slide will be mounted horizontally and moved on a lead screw driven by a stepper motor. The resulting mechanical package will be more compact than the Jasmine configuration, but will be able to use identical electronics.

Electronics Modifications

Most of the electronics need to be scaled up for the higher resolution and multiple channel features. The one thing that gets easier is maintaining a constant light integration interval. The Reticon light integration time *for each pixel* is the interval between pixel reads; the MARIT integration time *for each scan line* is the interval between scan clocks. This provides an opportunity to stop the data clock when the FIFO is full, an operation that is not possible with the Reticon device.

Gain/Offset RAMs

Jasmine provides 6 bits of gain and 6 bits of offset correction per pixel with 3 1024x4 RAMs (12K bits). MARIT will require 192K bits of correction, most easily implemented with 12 16Kx1 RAMs. Note that only 3264 out of 4120 elements would be used to image 8.5", so providing only 4096 correction elements per scan line is no problem.

Control Signals

The two signals which control the scanning operation of Jasmine are *start* and *setDelay*. Each passes 4 bits of data from the controlling processor, *skipCount* and *delayCount* respectively. After each start pulse, the Jasmine finite state machine clocks out all samples, digitizing 1024/(*skipCount*+1) of them, and waiting *delayCount* mseconds after each digitized sample. The MARIT chip can also be controlled by two signals: *start* and *clock*, with data bits *skipCount* and *clockControl*. The bits in *clockControl* are {*scan,shift,discardLine*}. After each *clock* pulse, the specified combination of *scan* and *shift* clocks is emitted. After each *start* pulse all samples are clocked out, digitizing 1030/(*skipCount*+1) of them if *discardLine* is zero. Maybe this should be 1024 samples clocked out, digitizing 1024/(*skipCount*+1), in which case the first 6 pixels are garbage due to integration from previous scan line. The delay control is provided by replacing the Jasmine *DelayDone* line (currently the carry bit from the delay counter) with the FIFO InputReady signal. This also makes external control much easier, since the FIFO will almost always be full, and delays in reading out data will not cause any samples to be lost.

The clockControl bit *discardLine* is used to enable flushing a full or partial scanline without reading samples from the FIFO. The state machine input Seq.Sample will be ANDed with discardLine', so that no samples will be digitized during the line flush. In order to guarantee that DelayDone will be true while flushing samples, discardLine' must also be ANDed with ResetCtrs' as imput to the FIFO MasterReset'. Flushing requires about 4msecond per sample, a maximum of 4.12mseconds per scanline.

DC Restoration

After the data clock goes low, the Reset line must be clocked high. In the time between the falling edge of Reset, and the next data clock rising edge, the nominal level for black appears on the output pins. This is the period analogous to the Reticon Recharge period, and the same DC restore must be done.

Channel Selection

The MARIT chip will deliver multiple wavelength samples interleaved. The Jasmine/Mimosa interface will allow any combination of channels to be digitized. An additional control signal *SetChannels* is provided, with the four data bits indicating which of the four channels are to be used. These four bits are cycled in a shift register at each ScanClk. The shift register output is ANDed with the state machine input signal *Sample*. The two low order address bits are held in a separate counter, and are used as input to a 4:1 analog multiplexor, gating the appropriate channel to the hold amplifier for A-D conversion. The carry out from this counter provides the *data* clock to MARIT, and is the additional input bit for the state machine to determine when to do the 4-channel parallel DCRestore and Charge Transfer operations. With this additional input bit, it is necessary to replace the 512x8 PROM by a 1024x4 or 1024x8 PROM. A 1024x4 will be a slight hassle since there are 5 nextState bits, the fifth of which will have to come from the 32x8 PROM which only has the currentState bits as inputs. SMOP.
The main loop of the state machine becomes:

```
UNTIL ScanDone DO
   VirScanClk;
   IF DataClk THEN
      BEGIN
      Reset;
      DCRestore;
       END;
   IF Sample THEN
      BEGIN
      AnalogOn; --transfer correct element to hold amplifier
      StartAD;
      Wait[8]; --8 cycles for A-D to finish
      END;
ENDLOOP;
```

Operating Modes

A number of configurations can be supported with the electronics outlined above. The control for some of these modes is detailed here.

Time-Delayed Integration

Using the standard MARIT chip with standard Jasmine optics limits the resolution to 96 scanlines/inch. To reduce the horizontal resolution to 96 pixels/inch without undersampling, time-delayed integration (TDI) can be used. Essentially, charge is integrated over all four apertures per column by clocking both *scan* and *shift* once per paper step. During the first scanline time, the top row of detectors is exposed to some scan line. After a shift and paper motion, the next row of detectors is exposed to the first scan line. After four shifts and paper steps, the scan line has been exposed through all four aperture masks, and is ready to be shifted out.

```
--1024x1024 TDI, 96 steps/in
DO
   WaitScanTime[];
   clockControl[scan+shift];StepPaper[];
   Start[];
   ReadScanLineData[];
ENDLOOP;

--1024x1024 TDI, 384 steps/in
DO
   THROUGH[1..4] DO
      WaitQuarterScanTime[];StepPaper[];
   ENDLOOP;
   clockControl[scan+shift];
   Start[];
   ReadScanLineData[];
ENDLOOP;
```

Undersampling

The MARIT resolution can also be reduced to 1024x1024 by only reading out one of the detector rows.

```
--1024x1024 undersampling, using one detector row
DO
   WaitScanTime[];
   THROUGH[1..4] DO
      clockControl[scan+shift];
   ENDLOOP;
   StepPaper[];
   Start[];
   ReadScanLineData[];
   --now, clear out shift rows
   THROUGH[1..3] DO clockControl[shift];ENDLOOP;
   clockControl[discardLine];
   Start[];
ENDLOOP;

--1024x1024 undersampling, using four detector rows
DO
   WaitScanTime[];
   THROUGH[1..4] DO
      clockControl[scan+shift];
      StepPaper[];
   ENDLOOP;
   FOR i IN [1..4] DO
      Start[];
      ReadScanLineData[row[i]];
   ENDLOOP;
ENDLOOP;
```

Full Resolution

Full resolution is only possible with a 384 step/inch paper transport. The data will appear in staggered order, and must be destaggered by the controlling processor.

```
--4096x4096 staggered output
DO
   WaitScanTime[];
   THROUGH[1..4] DO
      clockControl[scan+shift];
   ENDLOOP;
   StepPaper[];
   FOR i IN [1..4] DO
      Start[];
      ReadScanLineData[row[i]];
   ENDLOOP;
ENDLOOP;
```