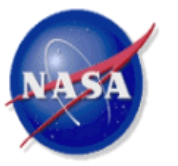


Development of a Portable Videoscope – An Example of Engineering System Design and Integration

Ray Bachnak, Ph.D., P.E.

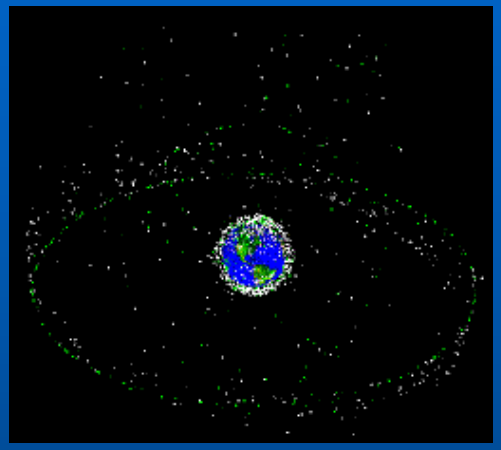
Department of Mathematical and Physical Sciences
Texas A&M International University

Outline

- Why this project?
- Desired features of the PEVIT
- Approach
- Determining a light source
- Overlaying physical parameters over video
- Conclusion

Why PEVIT?

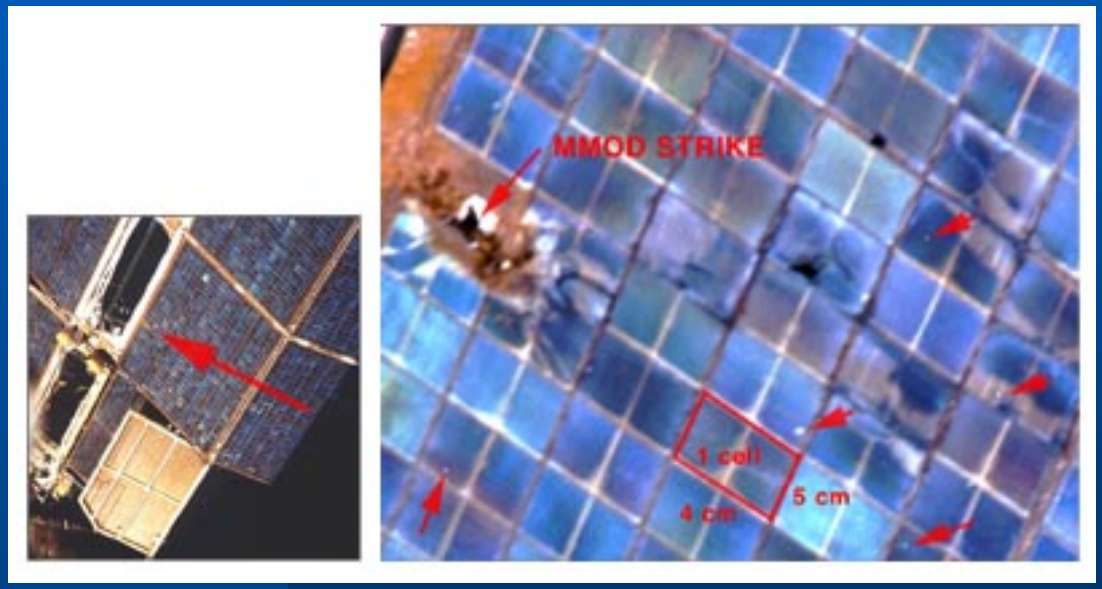
- Low Earth Orbit (LEO) is the region of space within 1,300 miles of the Earth's surface
- LEO is cluttered with millions of naturally occurring Micro-meteoroid and Orbital Debris (MMOD)
- It is estimated that 11,000 objects larger than 10 cm are known to exist in the LEO. Particles between 1 and 10 cm in diameter is greater than 100,000
- Debris travels at speeds of around 7.5 kilometers per second
- The International Space Station (ISS) orbits the earth at an altitude of approximately 225 miles above earth



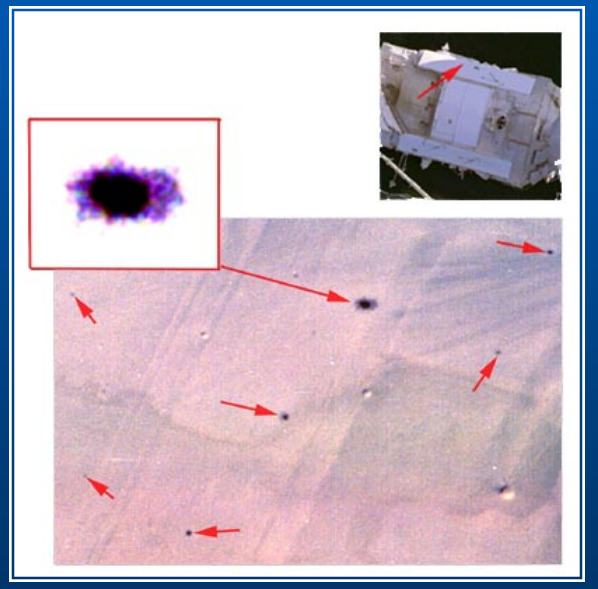
Simulation of orbital debris

The Problem

Orbital Debris Quarterly News, July 2006: *There were 41 MMOD impacts on the crew module windows during the ST-114 mission (Discovery). The largest impact was a 6.6 mm x 5.8 mm crater caused by a particle with an estimated diameter of 0.22 mm.*



Kvant-2 Solar Panel MMOD Strikes

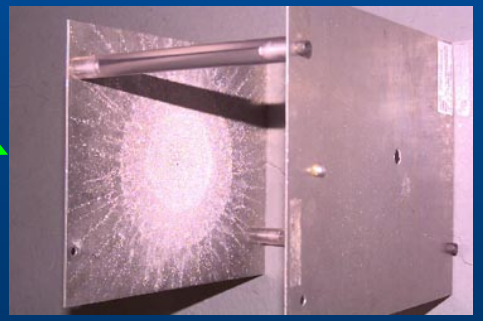


Kvant-2 Radiators

ISS Skin Panels

- The ISS is made of an aluminum shield, Wipple Shield, that maybe stuffed with Kevlar/insulation
- Bumper absorbs kinetic energy and breaks up particles
- Damage to skin panel ranges from: material deformation (dents), pitting, cracks, rupture

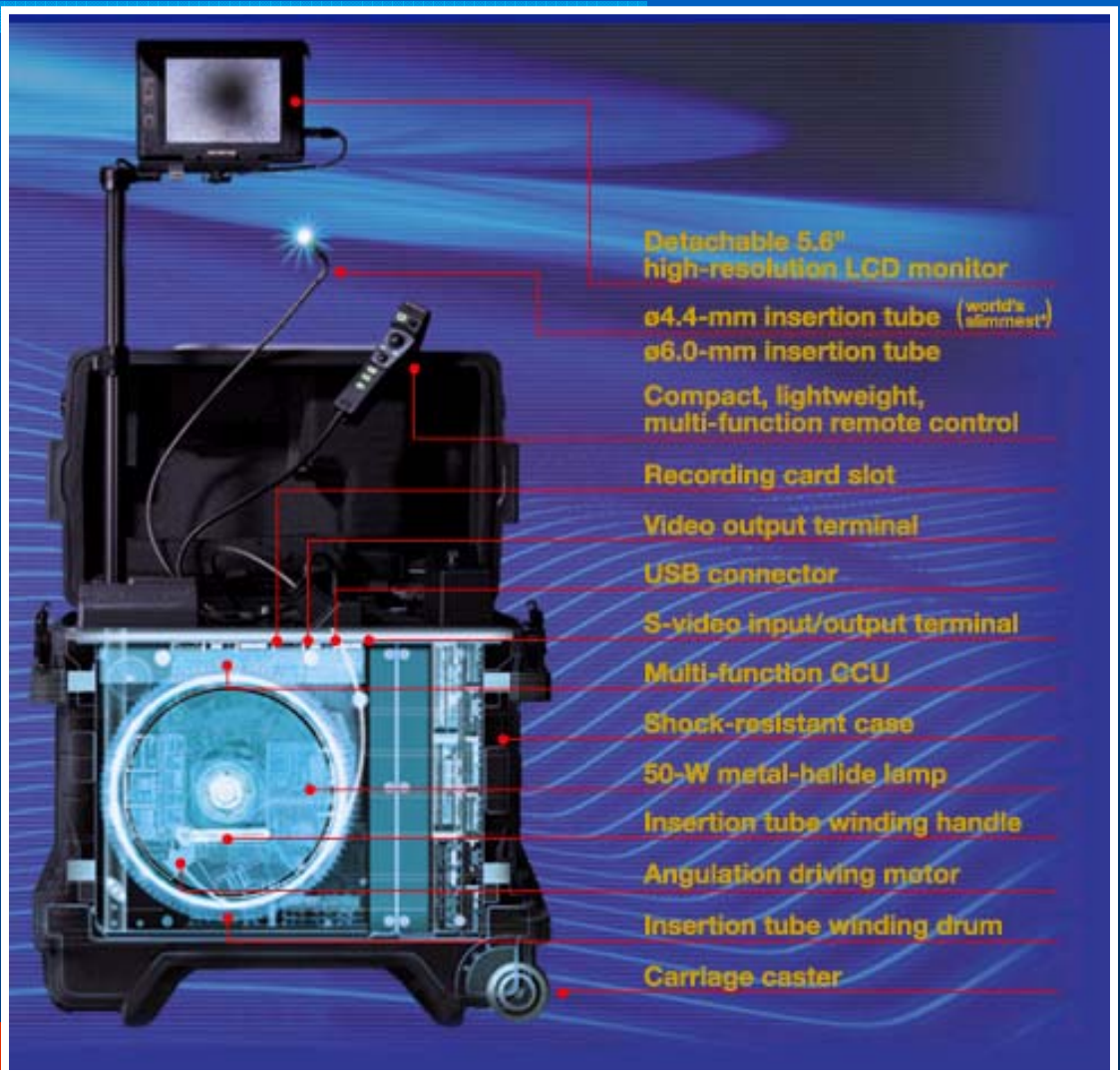
Exposed skin panels inside node 2 of the ISS



Whipple shield configuration

Olympus IPLEX Borescope

- Used for visual inspection of hard to reach areas
- Examples of defects include misalignments, cracking, pitting and wear



Objective

- **To design, develop, and test a device for on-orbit Non-destructive Evaluation (NDE) applications…… device called the PEVIT**

- **…..system will allow crew members in EVA space suits to perform inspection and transmit images via the existing Wireless Video System (WVS) for storage, processing, and analysis.**

Desired Features of the PEVIT

- **Utilize Commercial-Of-The-Shelf (COTS) components**
- **Redesign a videoscope by Olympus Industrial, IPLEX SA.**

  The process involves:

  - **Identifying the desired functions of the EVA borescope**
  - **Dividing the desired functions for implementation in two units:**

    IVA and EVA
  - **Identifying the components that must be redesigned or replaced**
  - **Optimizing the system design for image quality, focusing range, articulation ability, packaging size, and ease of use.**

Desired Features of the PEVIT

- 4-way mechanized angulation with incremental steps
- Self-centering reset button for angulation tip
- Video signal output compatible with WVS interface requirements
- A minimum of 3.5” display with deployable sunshade
- A controller that offers:
  - Toggle power On/Off and zoom switch
  - Light source brightness and contrast control switch
  - Digital zoom capability (3X Magnitude capability)

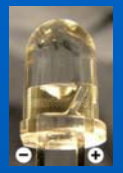
Desired Features of the PEVIT

EVA COMPATIBLE FEATURES:

- System Package is easy to operate by astronaut in EVA suit
- Compact and lightweight package; volume not to exceed 3 cubic feet
- Efficient light source
- Insertion tube outer diameter around 6 mm ……length about 1.5 m
- Rigid insertion tube sleeves for added flexibility

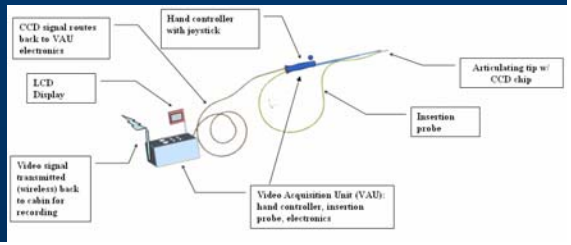
Two cameras: one CCD and one infrared

Modifying the IPLEX -Major Tasks



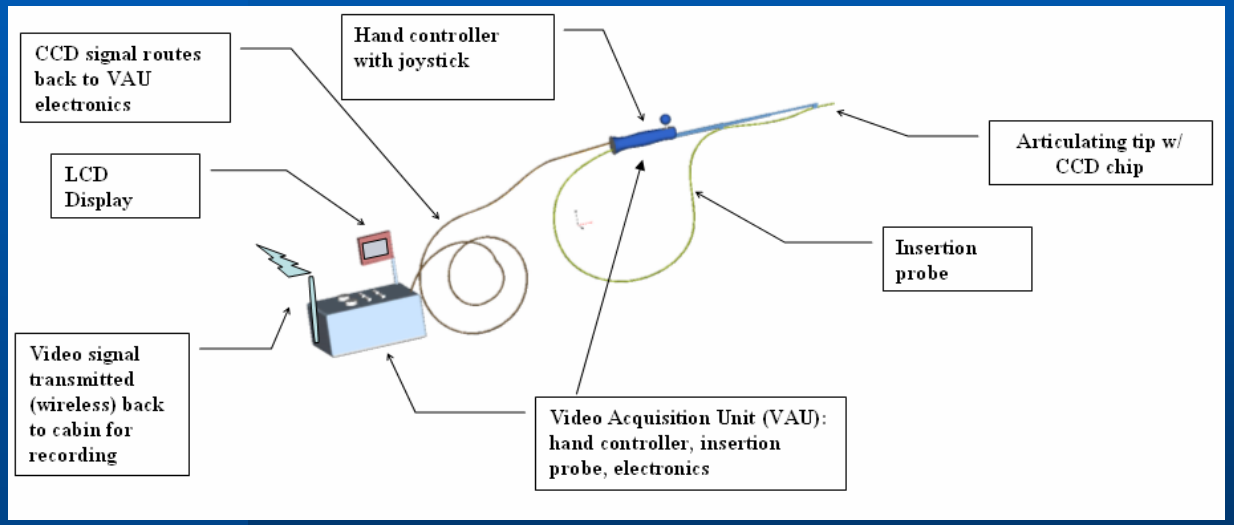
- Design and develop a low power efficient light source – White LEDs
- Determine an appropriate technology for image display – TFT display by PrimeView
- Develop interface circuitries to use the system in conjunction with the Wireless Video System (WVS) so that acquired images can be stored in a PC inside the International Space Station (ISS) and downloaded to earth

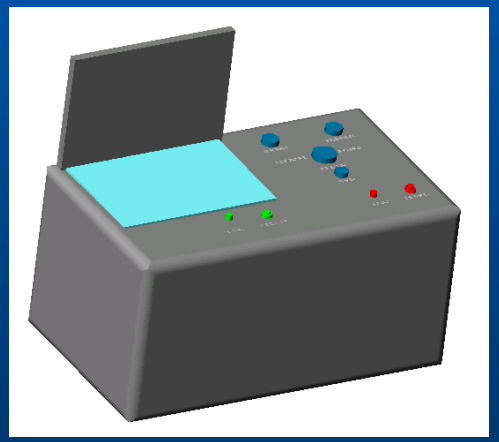
- Determine the power requirements of the system and select a power source – The REBA, 28W
- Develop a system for overlaying physical parameters over video signals
- Perform thermal, radiation, and electromagnetic interference tests.



System Components: EVA Unit

The EVA unit will consist of several components designed and packaged to allow easy operation by the astronaut





System Components: IVA Unit

The IVA unit will consist of a PC with a WVS transceiver and the IPLEX management software

Image Display

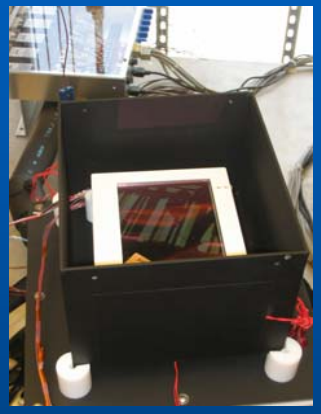
Table below shows a comparison of displays

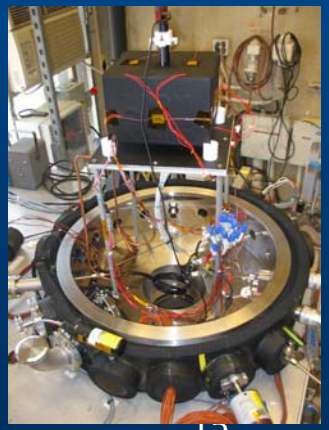
Parameter	OLED	LCD	A-TFT-LCD
Power consumption	Less tan 300 mW, 0.7" display	Approx 1 W, 7" display	Approx 350 mW, 3.5" display
Sunlight readability	Yes	No	Yes
Thermal range	-40 to 85 °C	-30 to 85 °C	-30 to 85 °C
Life Time	12,000 hrs	50,000 hrs	100,000 hrs
Response Time	Small, 100 µs	30-500 ms	30 ms
Color/brightness	Very good	Good	Very good
View Angle	170° or less	140° or less	170° or less

Image Display

6.5” Advanced TFT-LCD display by Sharp (LQ065T9BR51)

Parameter	6.5” Advanced TFT-LCD (LQ065T9BR51)
Aspect Ratio	16:9
Input signal format	NTSC
Brightness	220 cd/m^2
Dimensions (W x H x D)	155 x 89.2 x 12.5
Power consumption	5 W
Weight	205 grams
Operating temperature	-30 ^oC – 85 ^oC





Replaced by ---→ Model: PD064VT4
Manufacturer: Prime View

Estimated Power Consumption

Component	Estimated Power (W)
WVS Transceiver	TBD
Light Source	TBD
Display	05
Controller	02
CCD Camera	1.5
Infrared Camera	04
Total	**TBD**

REchargeable EVA BAttery

- 50 Sanyo 4/3A NiMH cells in a 5P-10S configuration; 12.5 V, 18 Ah

- Provides up to 2.33 A for 7 hours in a 11 to 14 volt range,

- Consists of 5 parallel strings of 10 NiMH cells in series,

- Power at I=2.33 A is : 12 V*2.33 A = 28 W,

- The power capacity is: 2.33 A*7 h = 16.31 Ah.

EHIP

6 V battery with a capacity of 10 Ah

- Both the REBA and EHIP can be recharged on the ISS and shuttle station

Comparison of Light Sources

Type	Lumens Per Watt	Ballast Power Usage	Life In Hours
LED (Light Emitting Diode)	28	-	Almost forever
HPS (warm light) (High Pressure Sodium)	150		16,000–24,000
LPS (Low Pressure Sodium)	100		16,000–24,000
Mercury Vapor	45		
Metal Halide	65		10,000
Compact Fluorescent	50	2 w	10,000
T8 32w Fluorescent	45	2 w (electronic)	10,000
T12 40w Fluorescent	30	17 w (magnetic)	8,000
Halogen	10	-	2,000
Incandescent	13	-	1,000 or less

Lighting Options

- A set of LEDs behind the CCD sensor, inside the tube, with light guided to the tip via fiber optics
- A set of LEDs inside the borescope with light guided to the tip via fiber optics
- An array of white LEDs placed around the CCD lens, at the tip of the insertion tube

Will LEDs Work?

- **Compare digital images taken by the IPLEX using the Metal Halide lamp or an LED under similar conditions**
  - **feature extraction (quantitative)**
    - **gray-level histogram**
    - **edge detection**
    - **image profile**
  - **image registration/transformation (qualitative)**

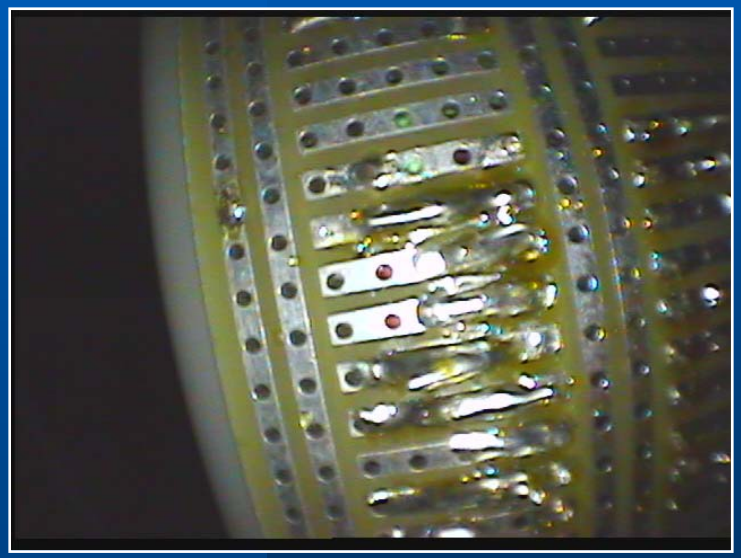
MATLAB Programming
Image Processing Toolbox

MATLAB Image Processing Toolbox is used for all image processing programming …….

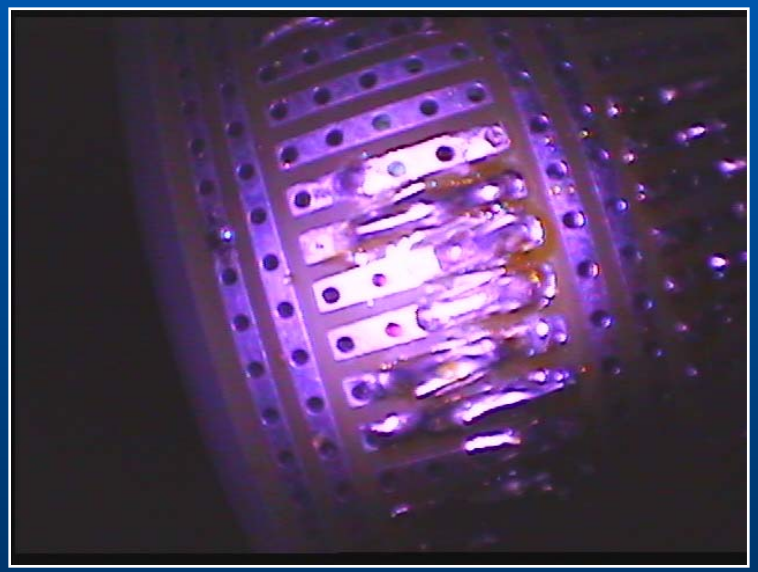
Procedure

Read, Display, Store, then Process

Image size: 480x640x3
921.6 Kbytes



METAL HALIDE

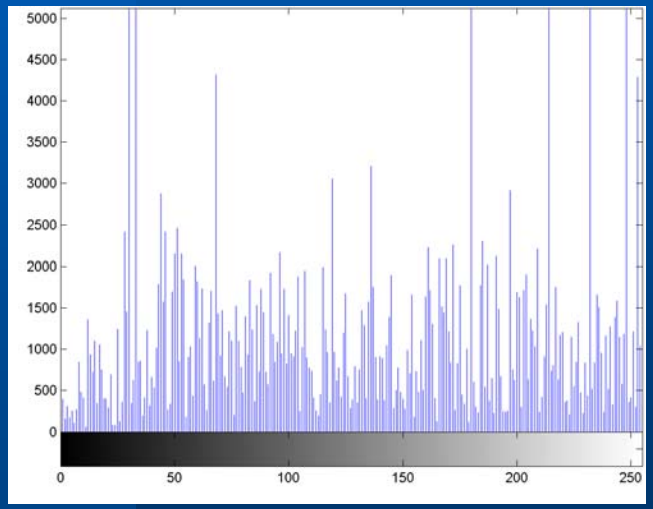


LED

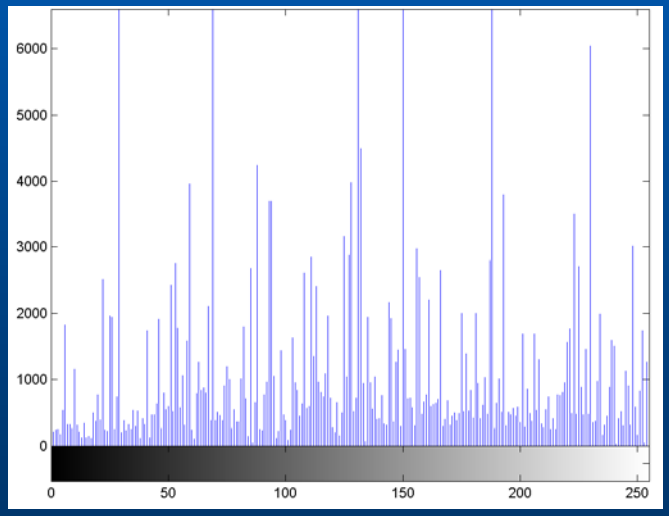
Image Feature Extraction- Gray-level Histogram

The histogram of an image represents the relative frequency of occurrence of the various gray levels in the image.

METAL HALIDE



LED

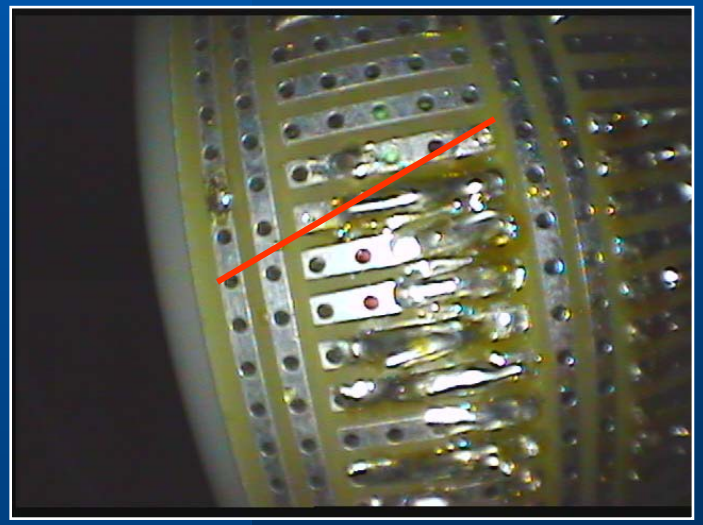


The histogram shows that the images are not the same ……..this feature extraction does not seem to be useful

Image Feature Extraction- Intensity Profile Along a Line Segment

MATLAB calculates and plots the intensity values along a line segment or a multiline path in an image

METAL HALIDE



LED

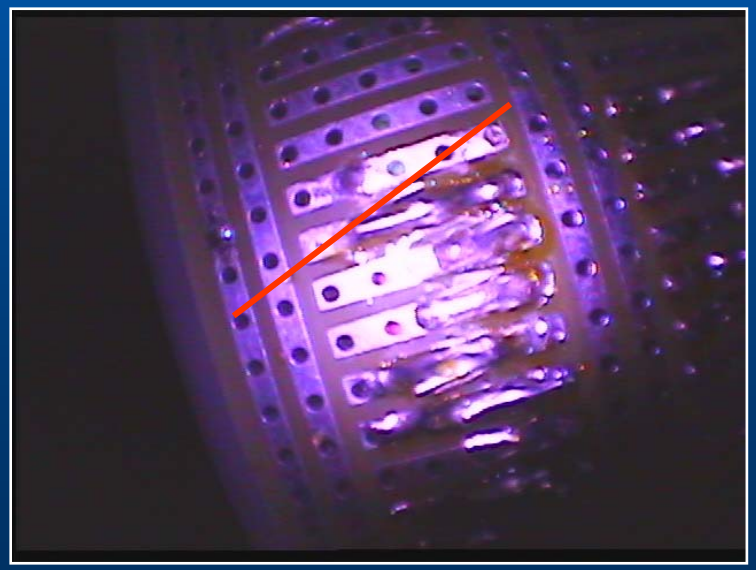
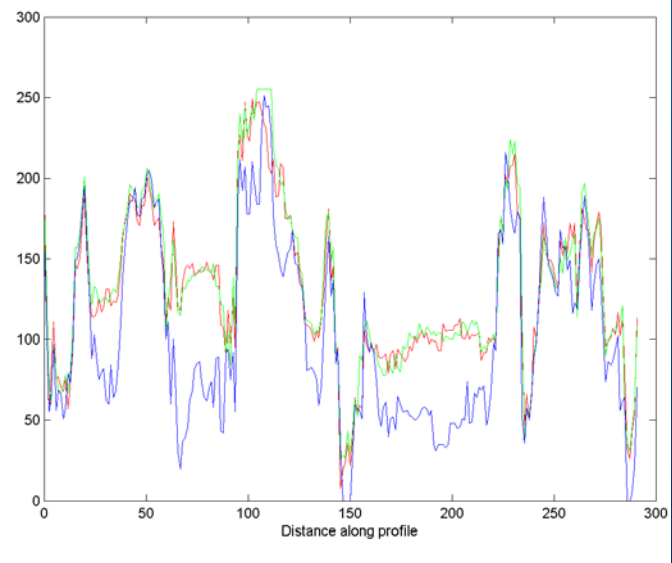
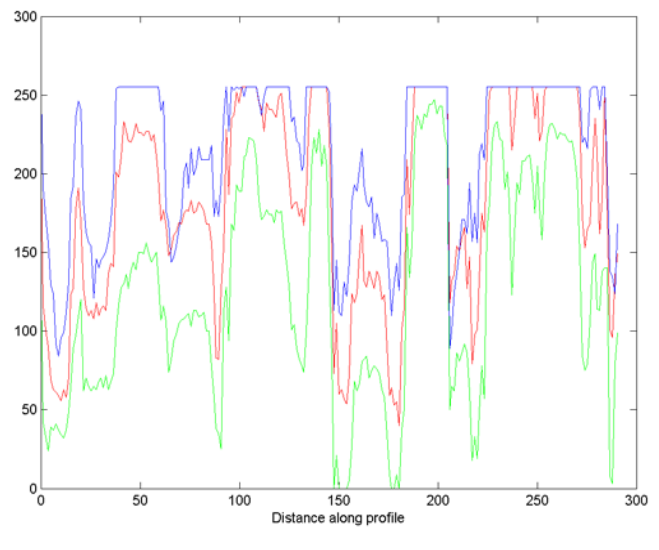


Image Feature Extraction- Intensity Profile Along a Line Segment

METAL HALIDE



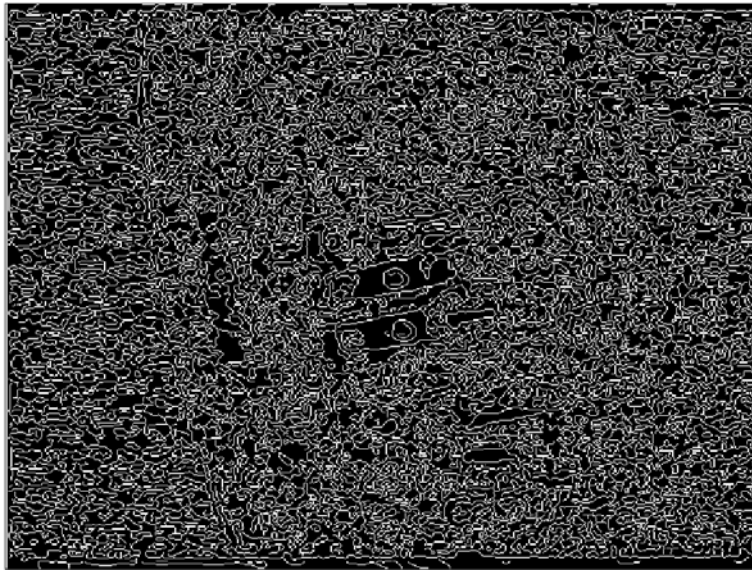
LED



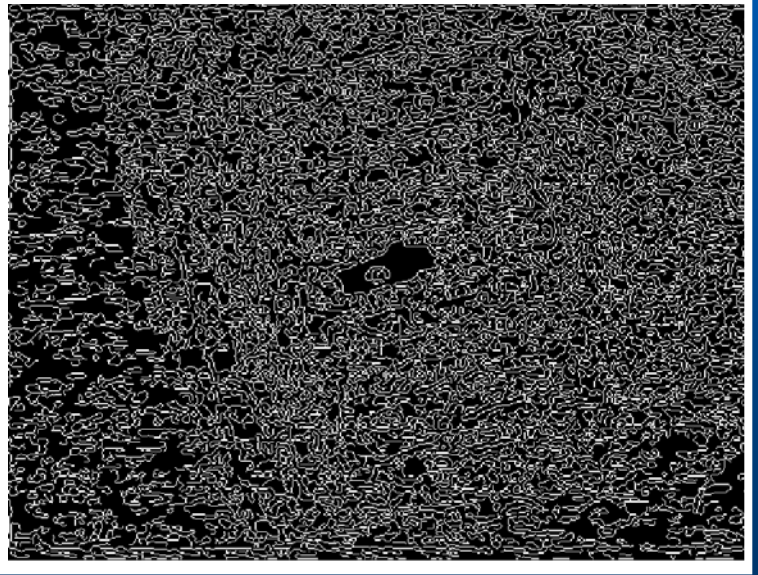
Images look different……..this feature extraction may not be useful.

Image Feature Extraction- Canny Edge Detection Method

METAL HALIDE



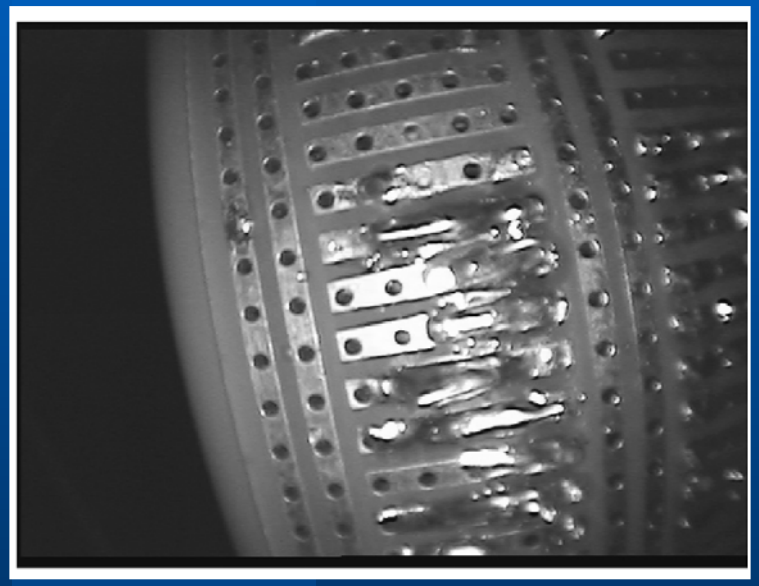
LED



Images look different……...

Image Registration

METAL HALIDE IMAGE AS BASE IMAGE



UNREGISTERED LED IMAGE

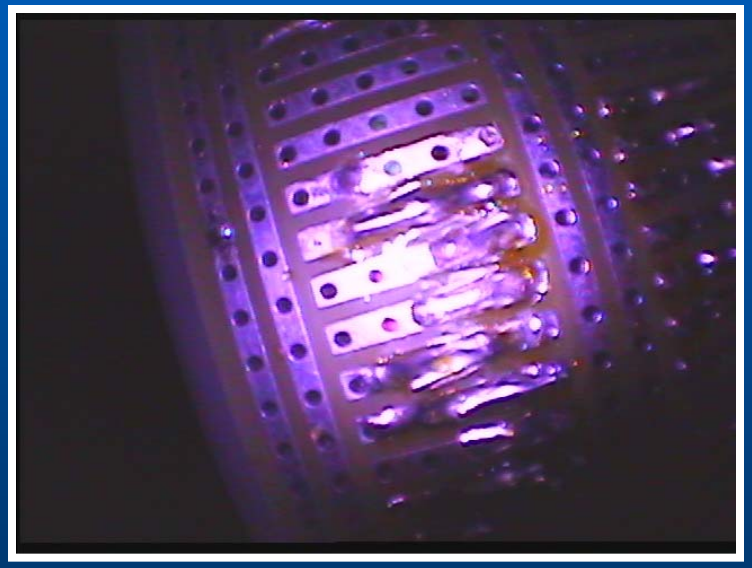
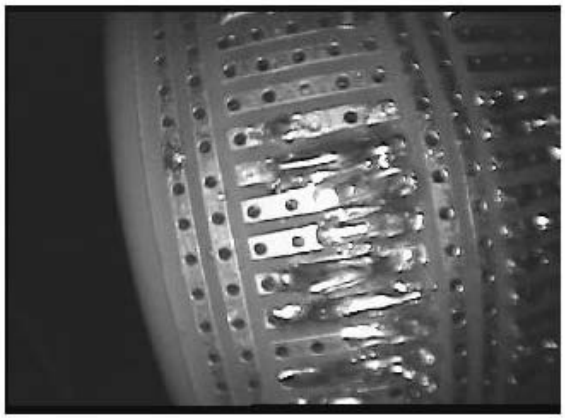
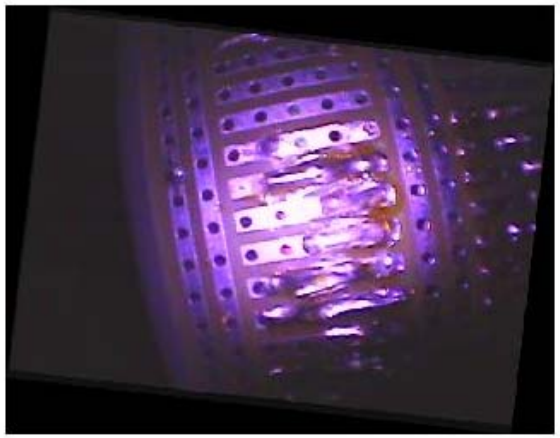


Image Registration

BASE AND REGISTERED IMAGE OF THE SAME ASPECT



[1277,947]



BASE IMAGE **REGISTERED IMAGE**

Based on the comparison of images shown above, the transformation was made possible because the two images are similar. Note that the second image is now in the same aspect and orientation as the base image. Except for the light intensity, the two images are very similar.

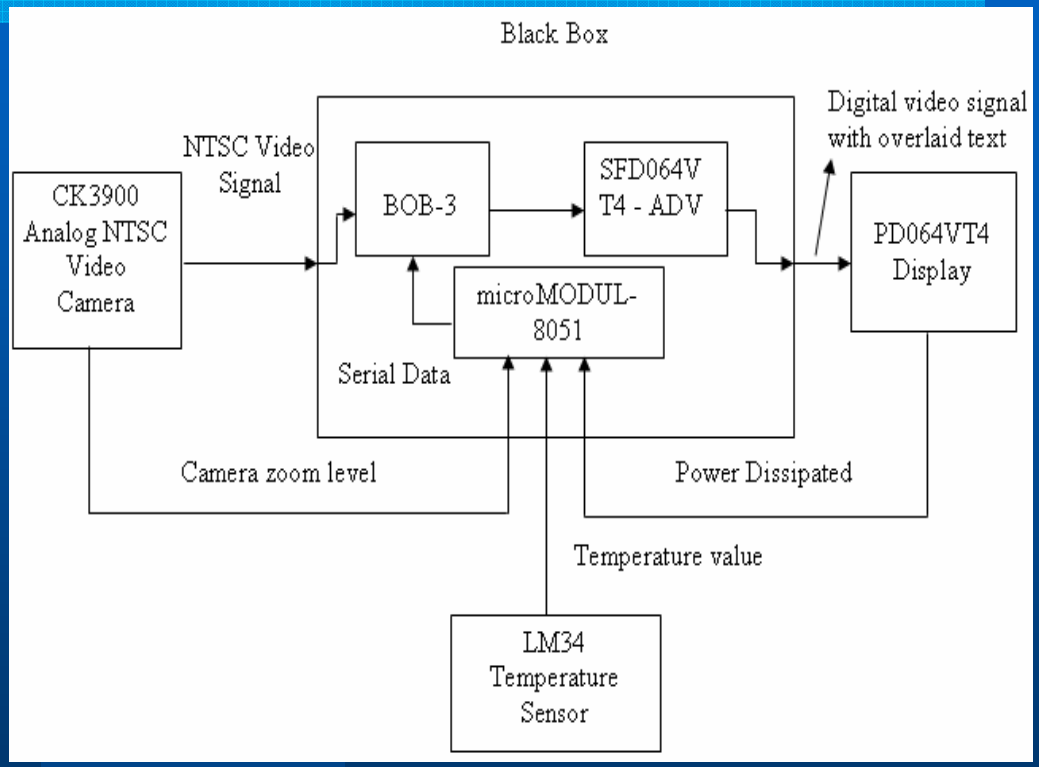
Conclusion and Selection

- LEDs promise significant reduction in power consumption
- The gray-level histogram, edge detection, and image profile don't offer conclusive results
- LED light source produces good images for visual inspection by an operator and is the best replacement light source for the Olympus IPLEX Borescope
- LED recommended and implemented

Data Overlay prototype

Design and development of a Video Conversion and Data Overlay (VCDO) prototype that will be used to enhance the features of a Portable EVA Visual Inspection Tool (PEVIT)

Overlaying Text Over Video



- Analog NTSC Video Camera
- microMODUL - 8051
- Basic Overlay Module (BOB - 3)
- TFT LCD Panel - Prime View PD064VT4
- LCD Controller kit - SFD064VT4 - ADV
- LM34 Temperature Sensor

Analog NTSC Video Camera

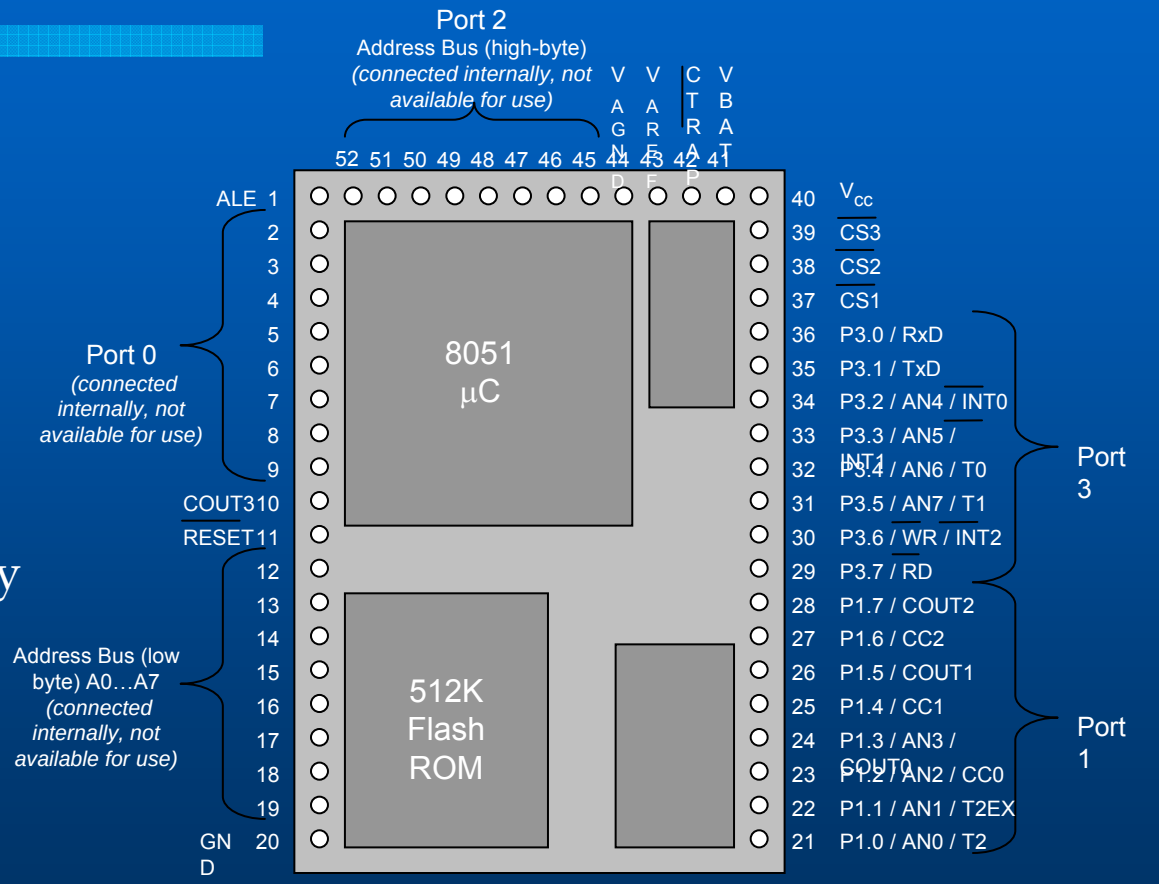
Model: CK3900N
Manufacturer: Meiji Techno

Features:

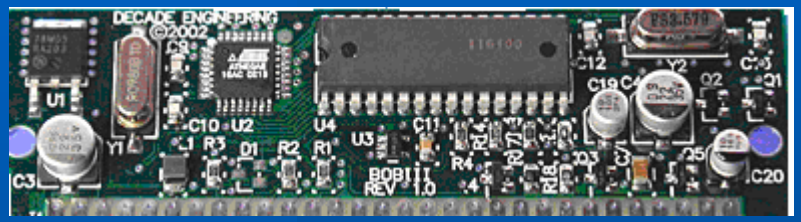
- **450 TV lines of horizontal resolution**
- **Super sensitive 1/2” CCD sensor**
- **NTSC: 525 lines, 768 x 494 @ 30 fps**
- **Employs 9 pin Dsub connector at camera rear panel for single cable connection**
- **Improved sensitivity and image performance**

The microMODUL-8051 SBC

- Four 8-bit ports (2 useable)
- Three 16-bit timer/counters
- 10-bit A/D converter
- 12 interrupt sources
- 128K external SRAM memory
- 512K external Flash ROM
- RS-232 serial interface



Basic Overlay Module (BOB - 3)



Model: BOB - 3
Manufacturer: Decade Engineering

- Features:
  - allows a microcontroller or PC display up to 680 characters on standard video monitors
  - controlled by a set of software commands

LCD Controller Kit

Model: SFD064VT4
Manufacturer: AZ Displays

Features
- Video Input Signal: NTSC
- Interface Panel type: PD064VT TFT LCD
- Backlight inverter board included
- Controller to convert analog signals to digital
- Backlighting: CCFL
- OSD unit included

TFT LCD Display Panel

Model: PD064VT4
Manufacturer: Prime View

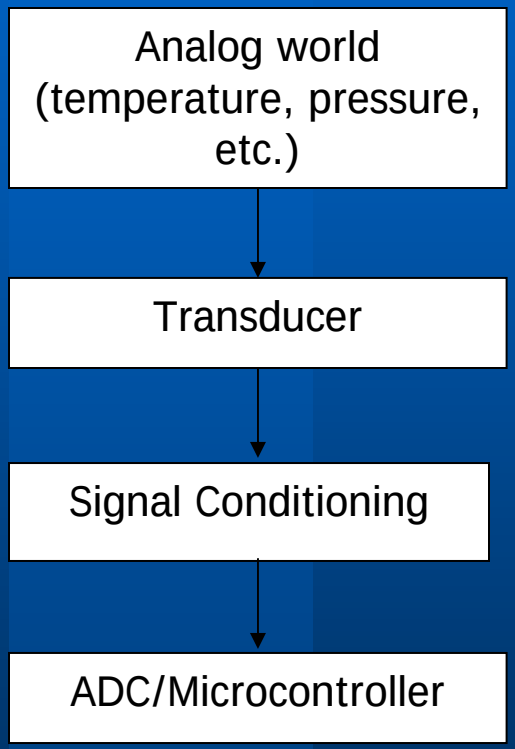
Features

- Higher contrast ratio of 400:1
- Brightness value of 400
- Interface: TTL
- Backlighting: CCFL
- Slim and Compact size

Hardware Design

- Data acquisition from the analog world
  - Temperature sensing circuit
  - Camera zoom capturing circuit
  - Power dissipation circuit
- Assembling data capture units
- Interfacing the components

Acquiring Physical Parameters



- Transducers produce an output in the form of voltage, current, charge, capacitance and resistance
- Transducer output has to be converted into voltage in order to input to an ADC
- Analog input to 8051 should be within 0-5V
- Signal amplification is required if input voltage range is much lower than 5V
- Signal conditioning is signal conversion, including amplification

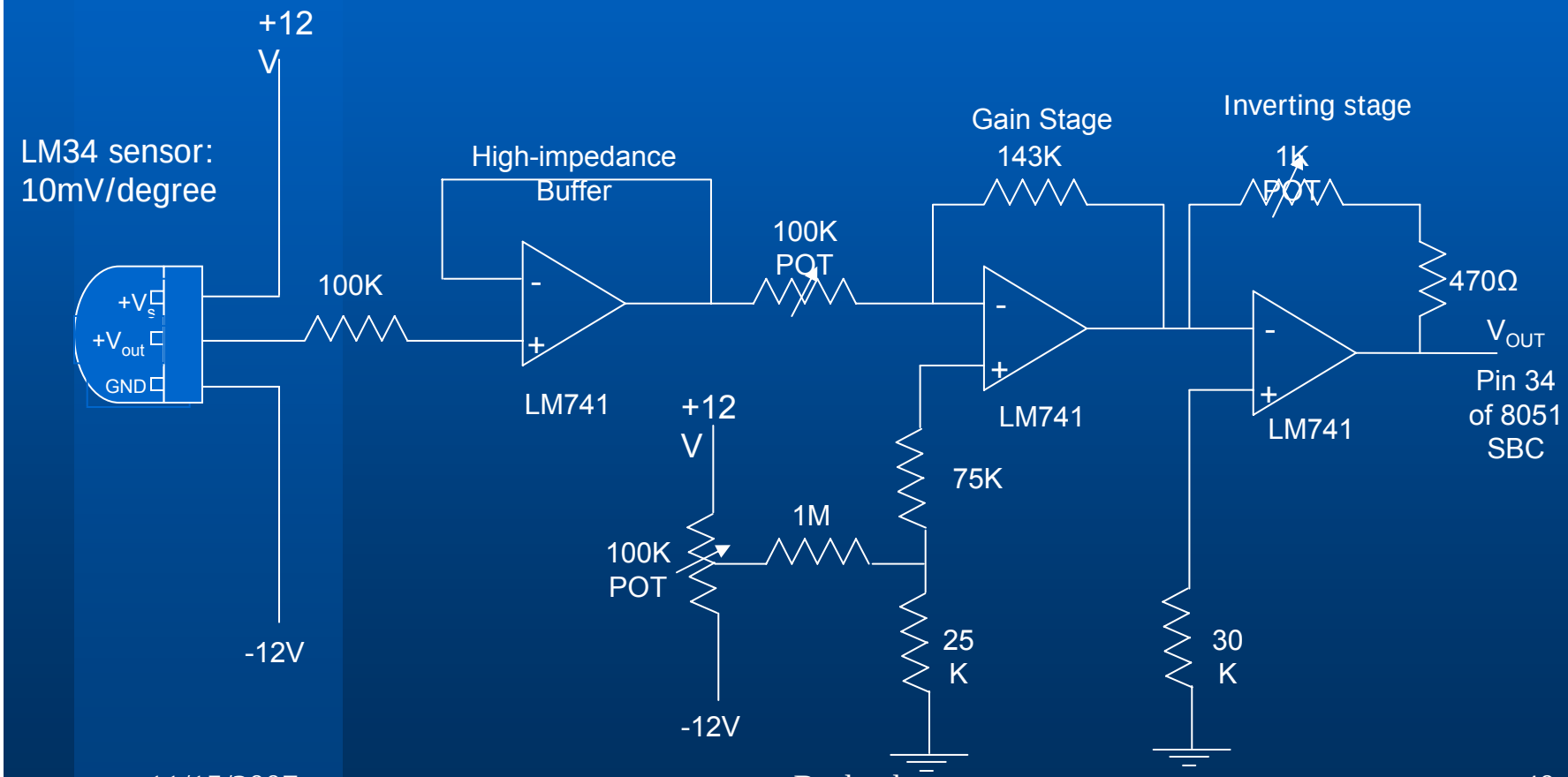
LM34 Temperature Sensor

Model: LM34
Manufacturer: National Semiconductor

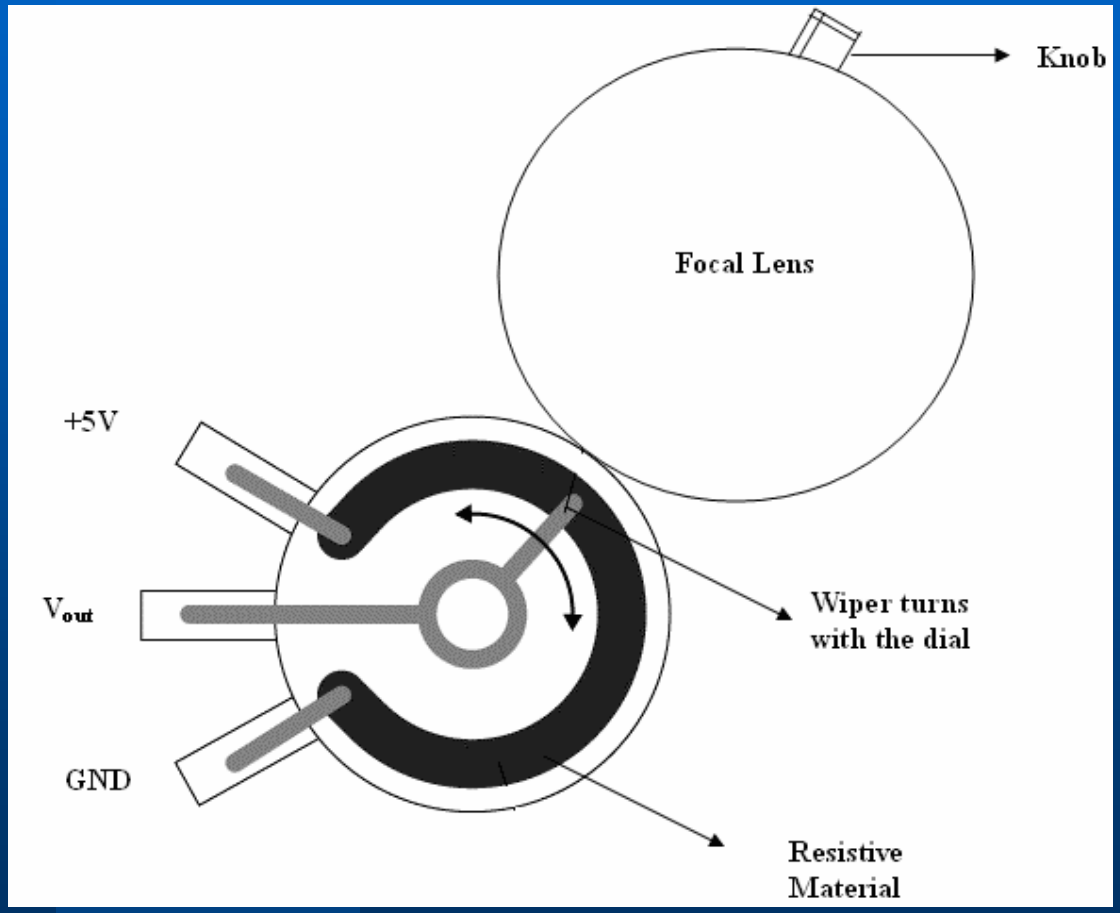
Features:

- **Voltage mode sensor**
- **Output voltage is linearly proportional to the Fahrenheit temperature**
- **Produces 10mV for every degree of temperature change**
- **Operational temperature range: −50°F to +300°F**
- **Low output impedance and precise inherent calibration**

Sensing Temperature

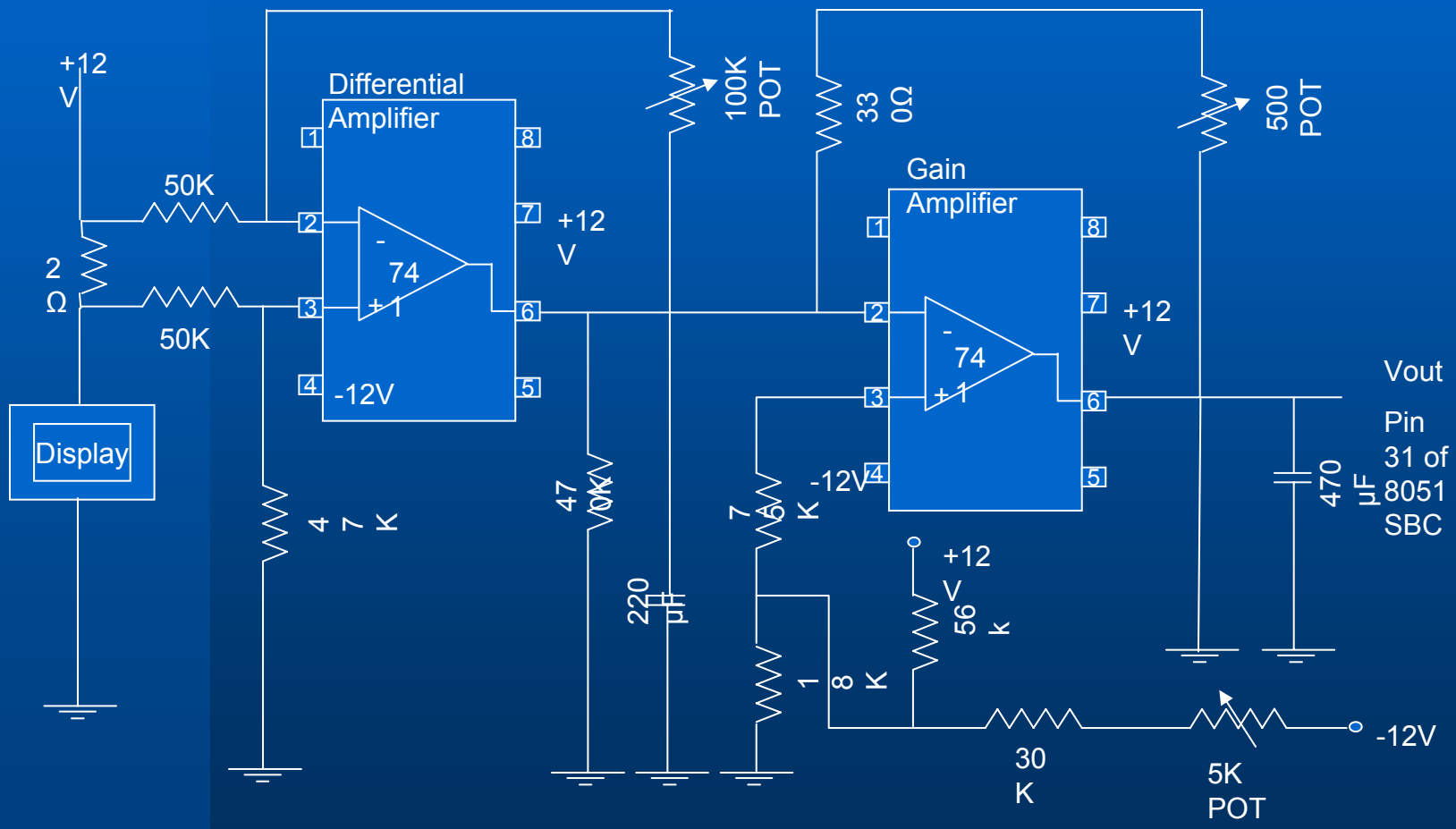


Sensing Camera Zoom

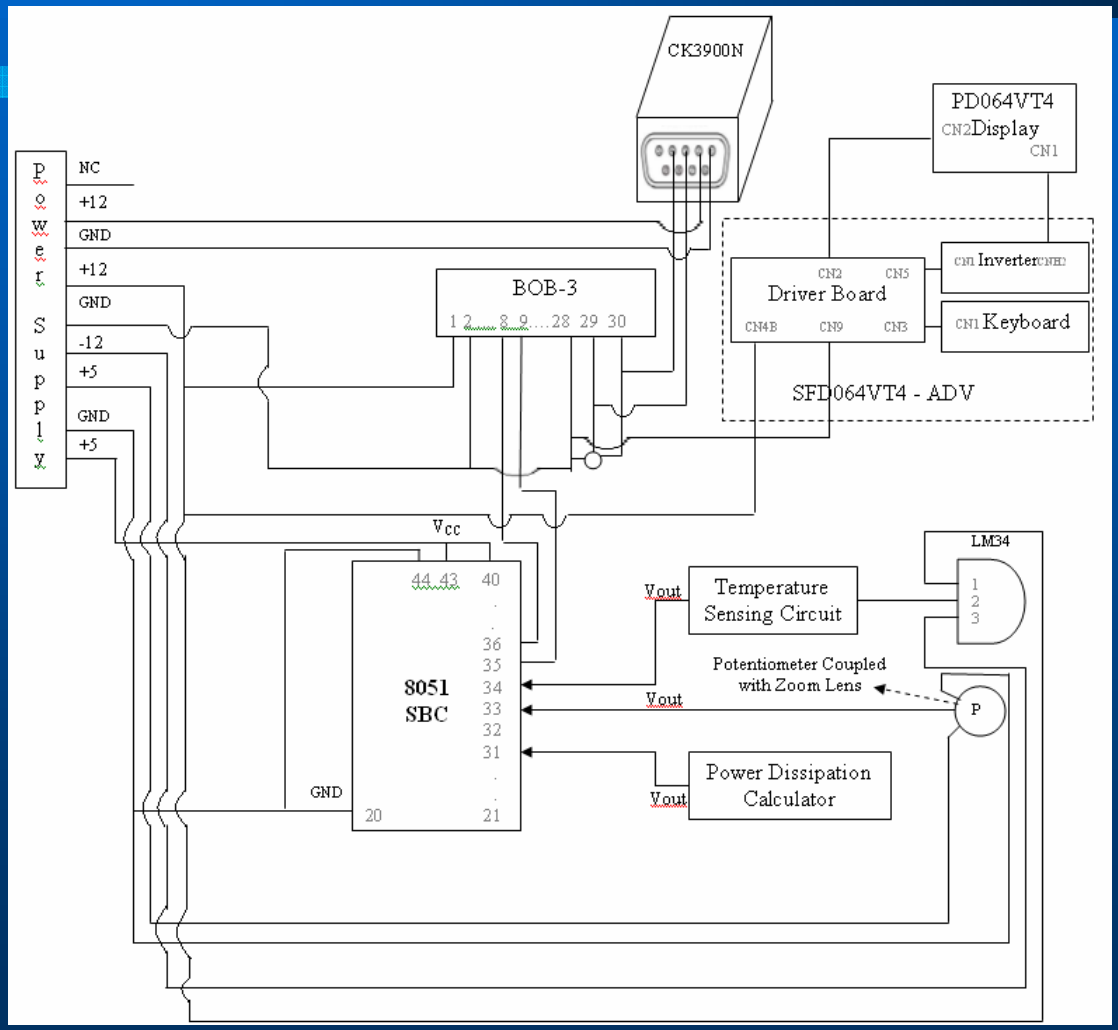


- Knob facilitates changing the focal length
- Displacement of the lens causes the dial move, which in turn, turns the wiper resulting in variable voltage output corresponding to lens angle of view
- Vout is connected to pin 33 of the 8051 SBC

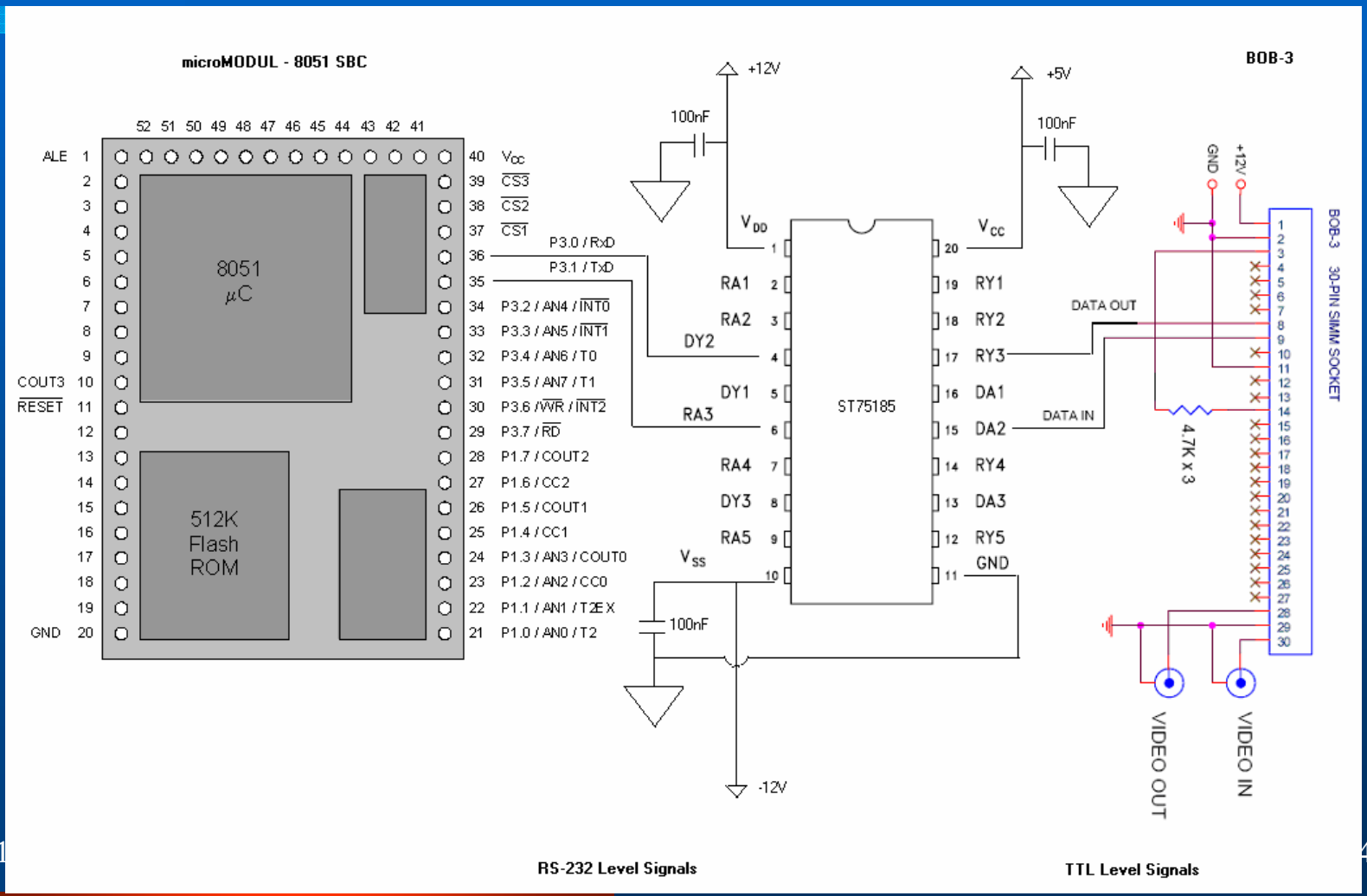
Sensing Power Dissipation



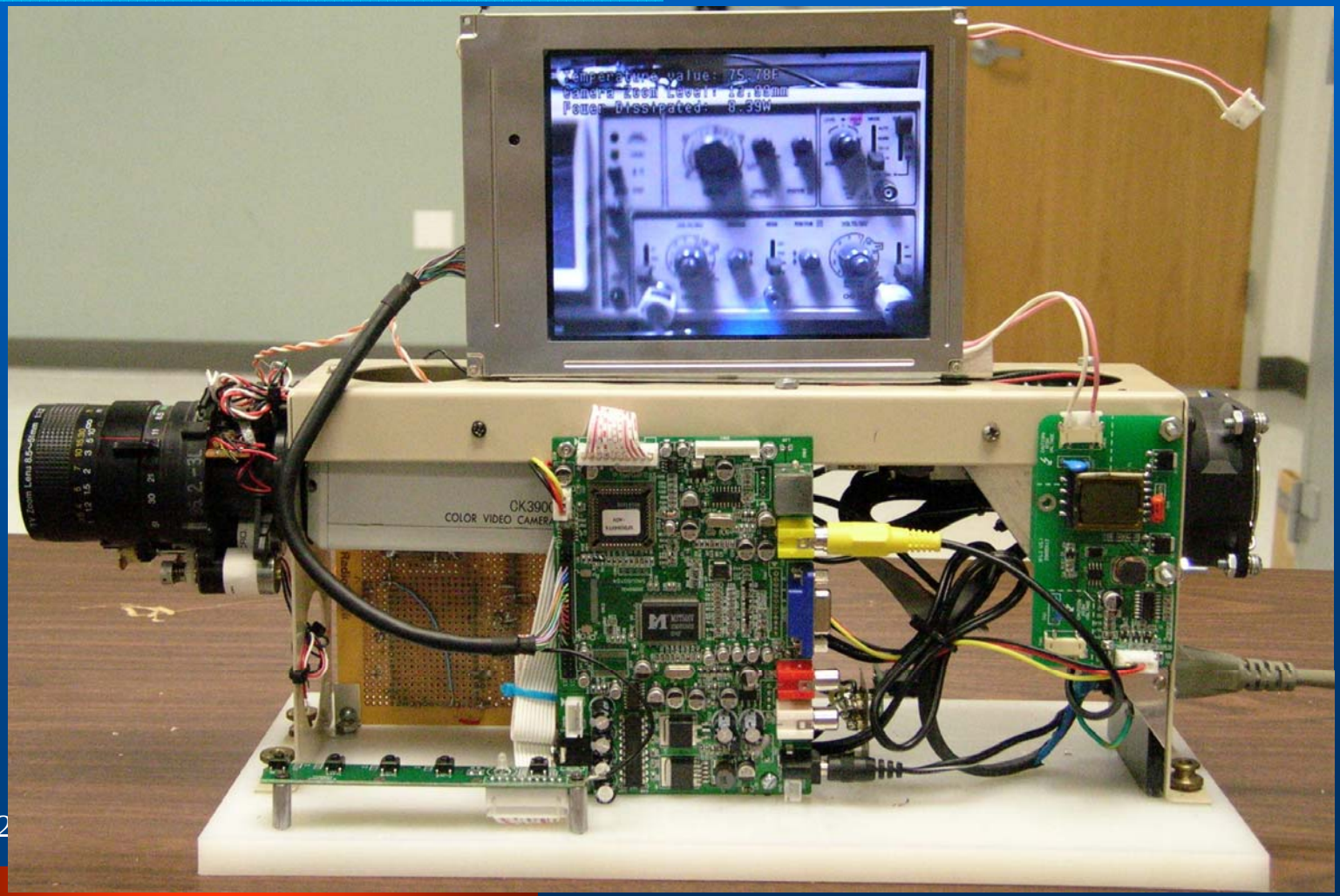
Detailed System Configuration



RS-232 to TTL


microMODUL - 8051 SBC
8051 µC
512K Flash ROM
ALE
COUT3
RESET
GND
P3.0 / RxD
P3.1 / TxD
+12V
+5V
100nF
ST75185
DY2
RA3
DY1
RA4
DY3
RA5
DATA OUT
DATA IN
4.7K x 3
BOB-3
BOB-3 30-PIN SIMM SOCKET
VIDEO OUT
VIDEO IN
-12V
RS-232 Level Signals
TTL Level Signals

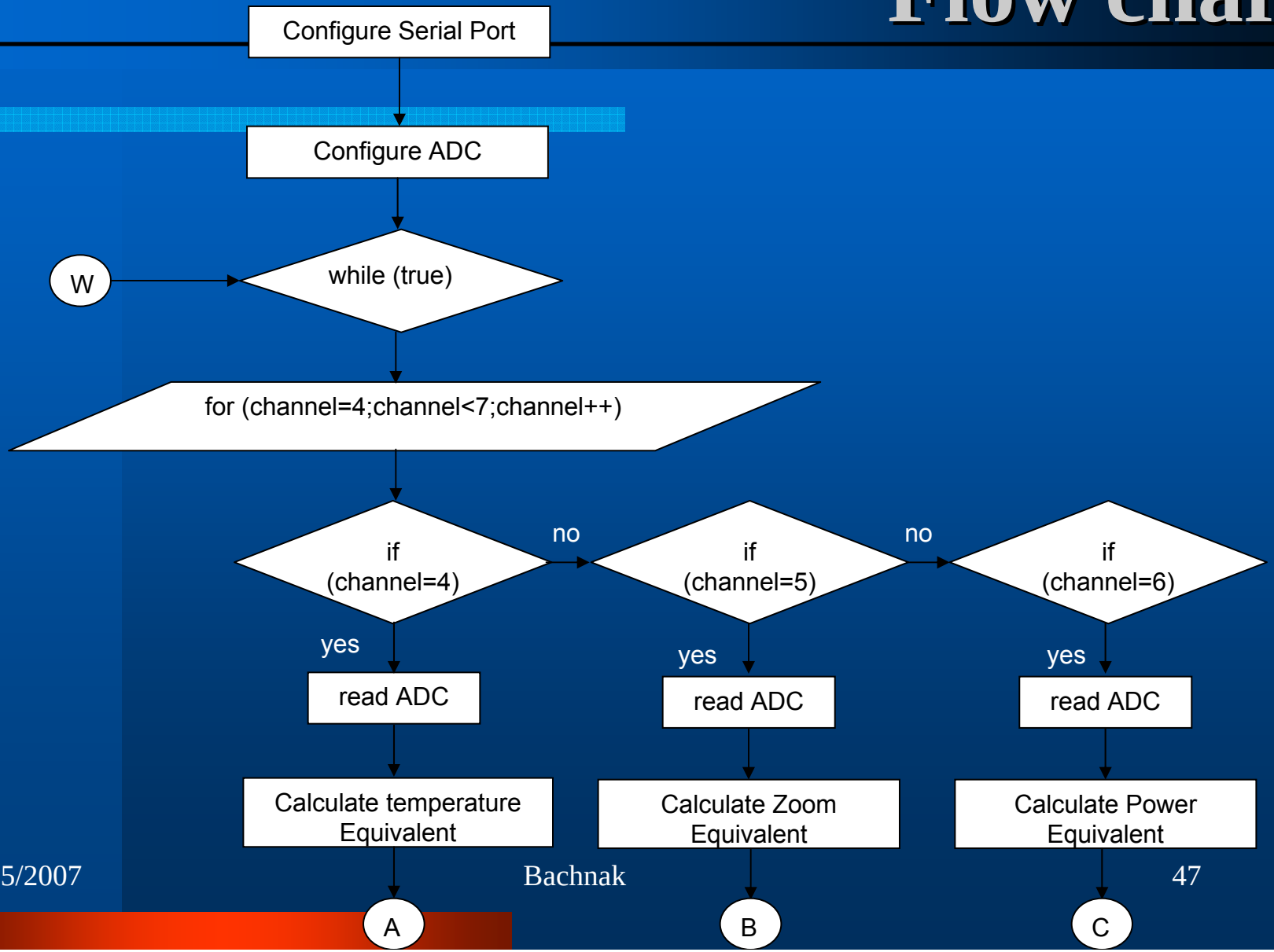
Prototype



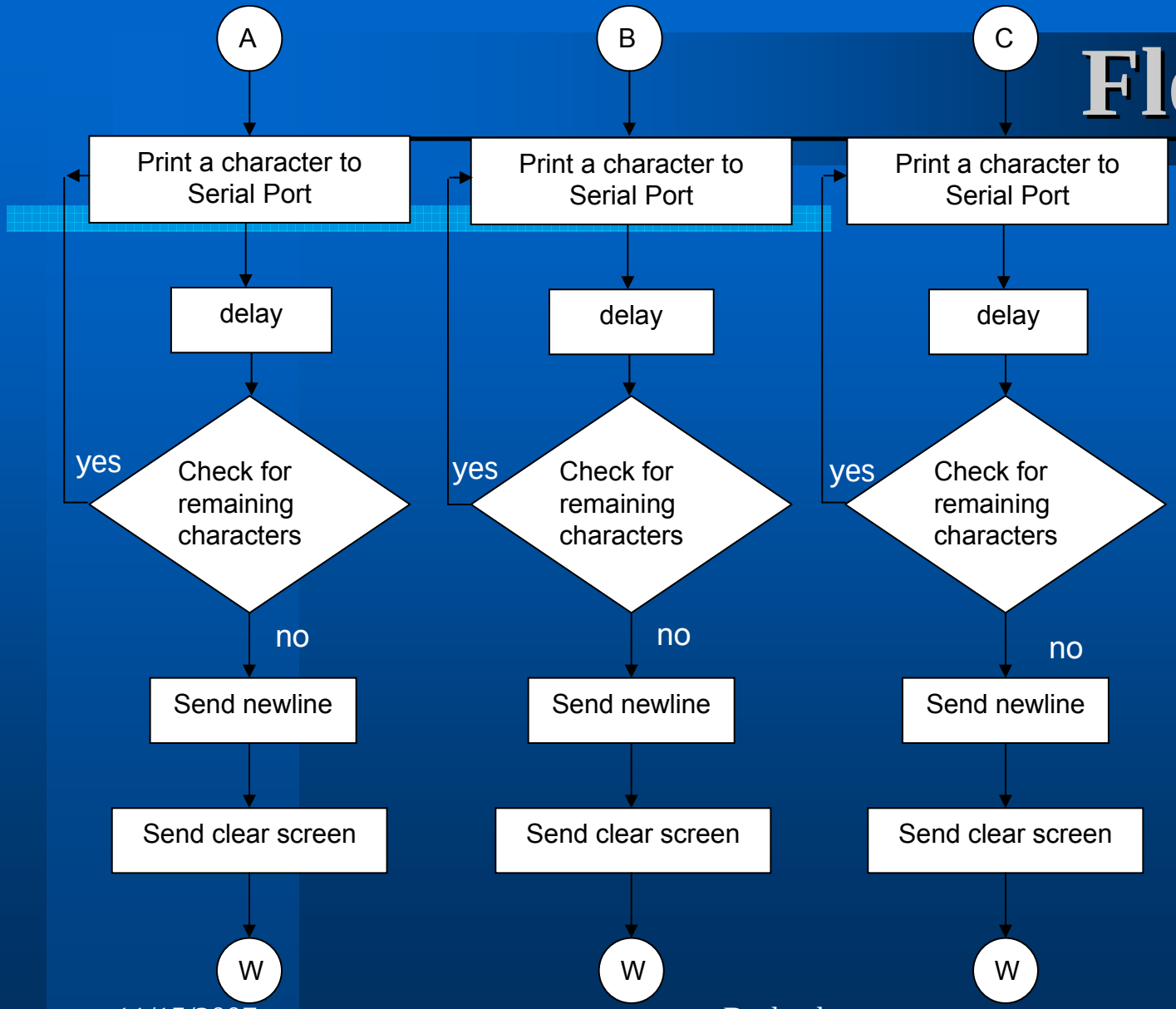
Software Development

- **Tools**
  - µVision 3
  - Flashtools98
- **Tasks**
  - Data Acquisition
  - Analog-to-Digital Conversion
  - Serial Communication
- **Languages**
  - C++ - Data acquisition, ADC, Serial Communication
  - Assembly – Delay function

Flow chart


Configure Serial Port
Configure ADC
W
while (true)
for (channel=4;channel<7;channel++)
if (channel=4)
no
if (channel=5)
no
if (channel=6)
yes
read ADC
yes
read ADC
yes
read ADC
Calculate temperature Equivalent
Calculate Zoom Equivalent
Calculate Power Equivalent
A
B
C

Flow Chart


A
B
C
Print a character to Serial Port
Print a character to Serial Port
Print a character to Serial Port
delay
delay
delay
Check for remaining characters
Check for remaining characters
Check for remaining characters
yes
yes
yes
no
no
no
Send newline
Send newline
Send newline
Send clear screen
Send clear screen
Send clear screen
W
W
W

Results- Temperature Data

Exp. No.	V (V)	T_t (°F)	Te (°F)	Error (Tt-Te)-°F
1	3	300	299	+1
2	0.75	75	74.75	+0.25
3	-0.04	- 4	-3.17	-0.8.3
4	-0.50	-50	-49.6	-0.4

T_t : Theoretical value of temp
T_e: Experimental value of temp error : (T_t – T_e) mm

Results- Zoom Data

Exp. No.	V (V)	Z_t (mm)	Ze (mm)	Error (mm)
1	4.30	8.5	8.52	-0.02
2	1.8	21	21.01	-0.01
3	0.9	33	33.01	-0.01
4	0	51	50.90	0.01

V : Voltage Applied Z_t : Theoretical value of zoom
Z_e: Experimental value of zoom error : $(Z_t - Z_e)$ mm

Results – Power Data

Exp. No.	V (V)	I (mA)	P_t (W)	Pe (W)	% error
1	12	700	8.40	8.39	0.01
2	12	550	6.60	6.50	0.1
3	12	400	4.8	4.7	0.1

V : Voltage Applied I : Current flowing through display P_t : Theoretical value of power
P_e: Experimental value of power Error : (P_t – P_e)

Conclusion

- The developed system accomplishes the task of overlaying text onto a digital video signal to aid the user in monitoring desired parameters
- Test results show reasonably accurate temperature, power dissipation, and zoom values.

Future Work

- Reprogram the flash to either capture additional parameters or to replace existing parameters
- Develop additional data capture units if needed
- Replace the micro-MODUL 8051 SBC with a PLD that better suits the application.