MULTI-SENSOR INFANT MONITORING SYSTEM

ECE Day Presentation
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BACKGROUND

- Sudden Infant Death Syndrome (SIDS):
  - Sudden unexplained death of an infant

- Industry affected: Biomedical

- Technology:
  - Infrared
  - Integrated Circuits

- Customer: Parents and Caregivers of infants

PROBLEM FORMULATION

- NIH/NICHD reports that "Back-to-bed" program significantly reduces SIDS occurrence by 50% since 1990
  - "Back-to-bed" program - designed primarily to stress that babies should be put to sleep on their back

- Existing monitoring technologies
  - Detect singular vital signs
  - Limited in scope

- Design Specifications
  - Mountable in typical bedroom, light weight; providing ease of travel
  - Work in light or dark room

- Regulations
  - Must meet the definition of a medical device in section 201(h) of the Federal Food Drug & Cosmetic (FD&C) Act
  - Must adhere to the Food and Drug Administration (FDA) regulation of a maximum level of 0.5 µg/mL for lead content products intended for use by infants and children

ALTERNATE SOLUTIONS

- Integrated Multi-senor Baby Suit
  - Wearable device which through contact with the infant at specific locations on the body can sense the infant's pulse rate, temperature and monitor the position

- Position Monitoring Mattress
  - Uses pressure sensors as well as a pulse detector and timer to monitor back-to-bed position of infant, respiratory and heart rate
  - Mattress comes with a crib mounted noise monitor, video camera and air sensor

- PAA (Position, Alternans, Apnea) Infant Monitoring System
  - Incorporates a means to monitor the **P**osition, **A**pnea and heart **A**lternans of an infant
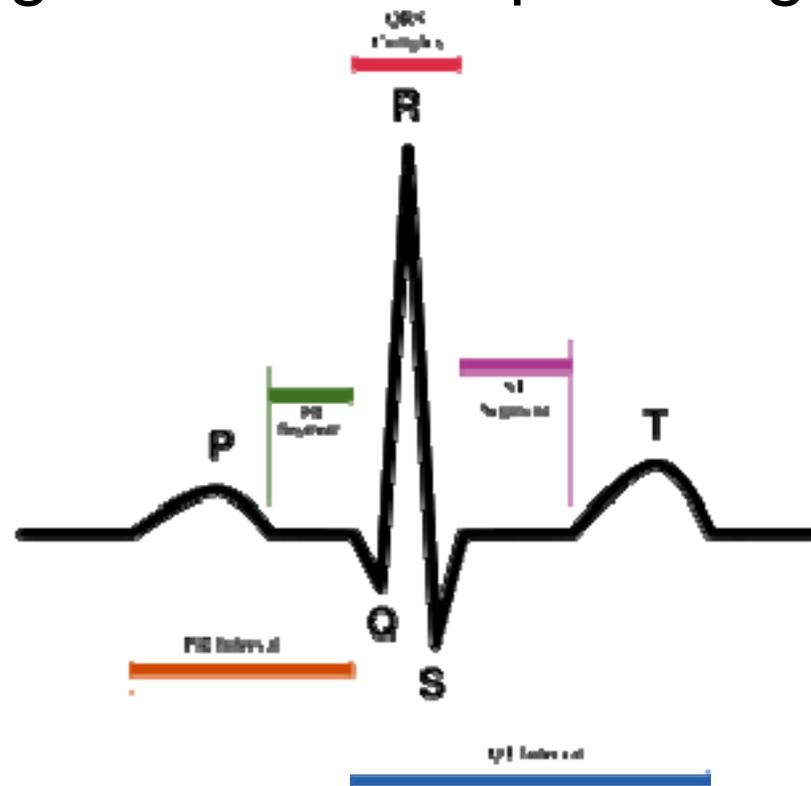
MAJOR (Hybrid) SOLUTION

○ Integrates the concepts and functionality of other alternate solutions to generate a unique design

○ Monitors:
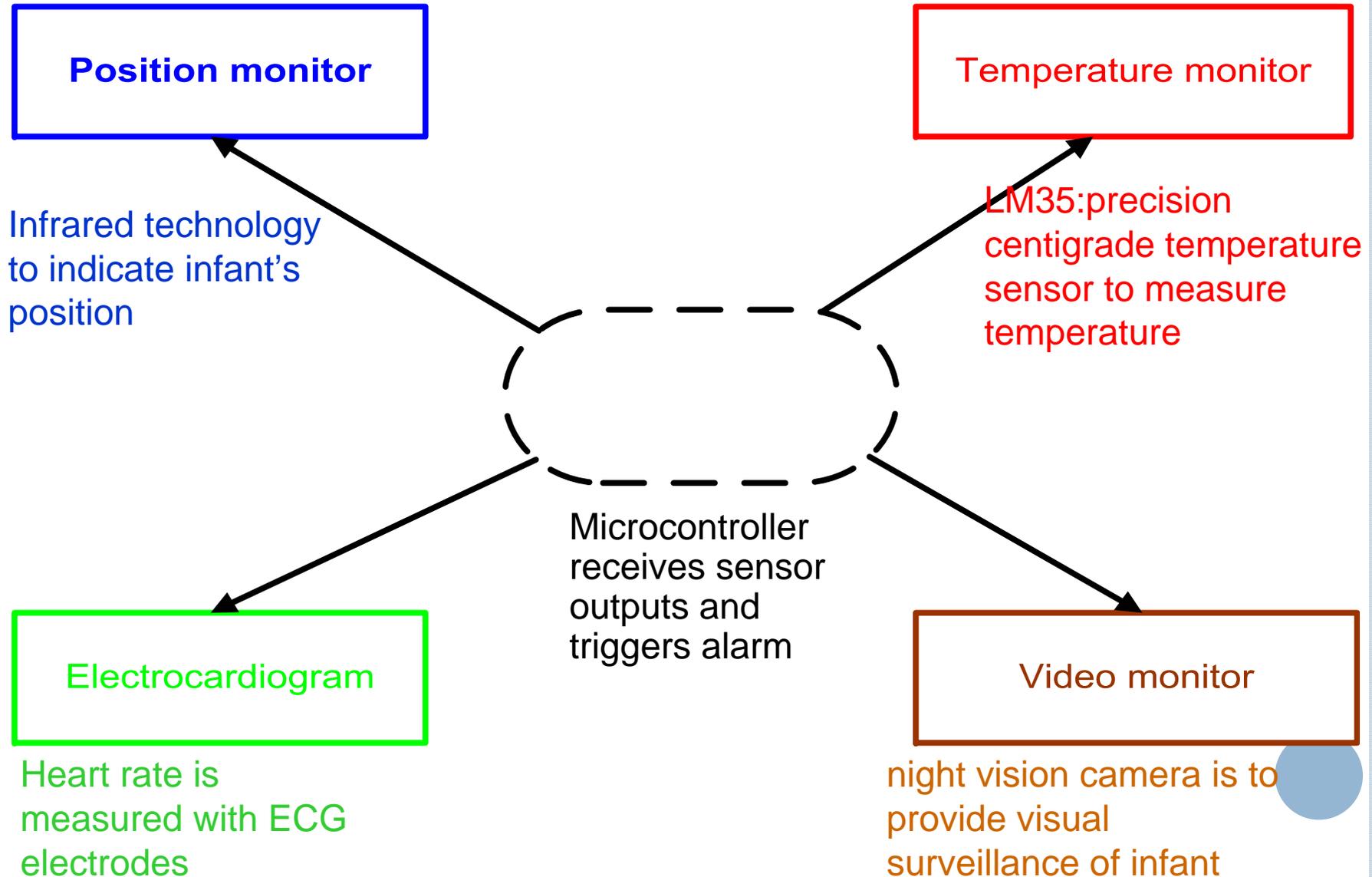 ➢ Position
  ➢ Temperature
  ➢ ECG
  ➢ Visual image
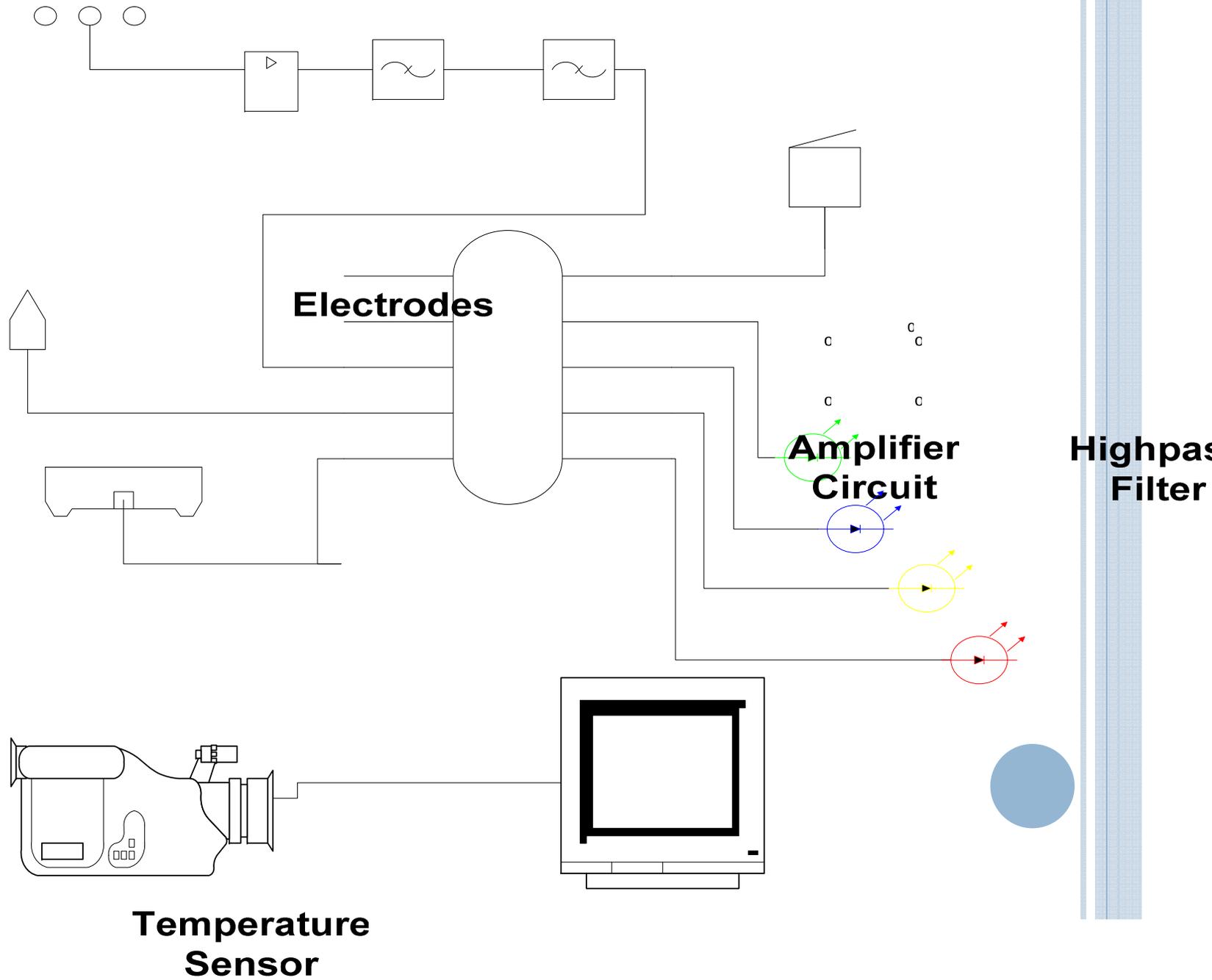
SELECTION OF TOP DESIGN

		Decision Matrix							
		Baby Suit		**Position Monitoring Mattress**		**PAA System**		**Hybrid**	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Safety/Intrusiveness	30	4	1.2	3	0.9	3	0.9	4	1.2
Ease of Implementation	15	3	0.45	2	0.3	2	0.3	3	0.45
Number of Signs Monitored	35	2	0.7	2	0.7	4	1.4	4	1.4
Price	20	3	0.6	3	0.6	2	0.4	3	0.6
Total Score			2.95		2.5		3		3.65
Rank			**3**		**4**		**2**		**1**

DESIGN OVERVIEW

Position monitor

Infrared technology to indicate infant's position

Temperature monitor

LM35:precision centigrade temperature sensor to measure temperature

Microcontroller receives sensor outputs and triggers alarm

Electrocardiogram

Heart rate is measured with ECG electrodes

Video monitor

night vision camera is to provide visual surveillance of infant

Multi-

DESIGN SCHEMATIC
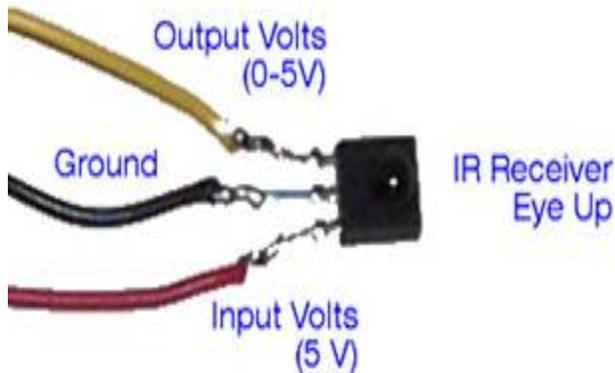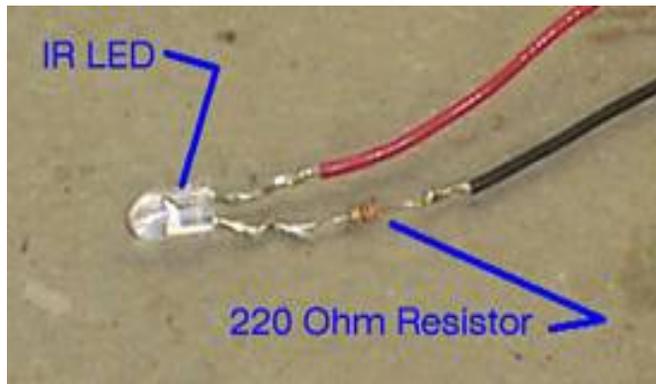
Electrodes

Amplifier Circuit

Highpass Filter

Temperature Sensor

POSITION MONITORING CIRCUIT

- **Non-intrusive approach to monitor the position of the infant**

- **Infrared detection of infant position (Emitter and Collector)**

- **Output of collector:**
  - ~0.005V, when IR is present
  - ~5.0V, when IR is absent

- **Range of operation is up to 2 feet**

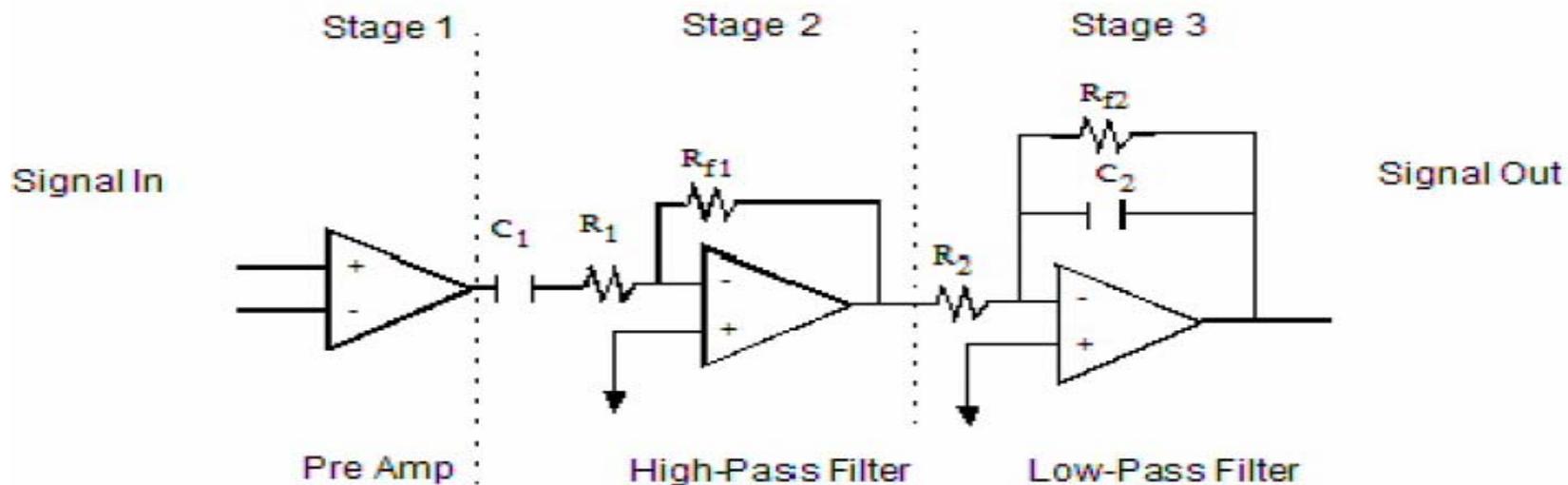- **IR LED or Emitter is cycled by a 38.5kHz PWM square wave**

TEMPERATURE SENSING CIRCUIT

- LM35 is a precision centigrade temperature sensor

- Output voltage ranges from 0V – 1V

- Linear Scale: 0.01V/°C

- According NIH, the normal surface temperature range for an infant under the age of 1 year old is 34.7°C – 37.3°C
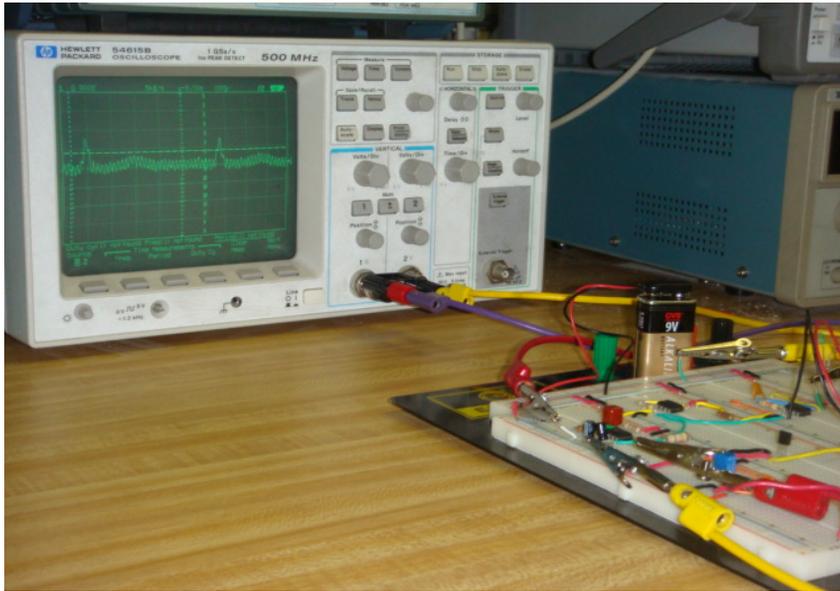
LM35

+5

PortA.0
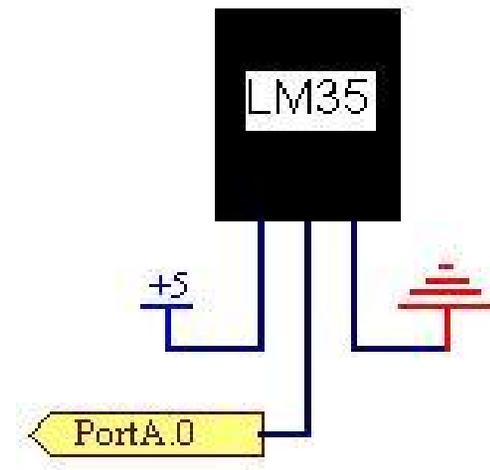
Obtaining ECG signals via Electrodes

- ECG are AC signals with: **peak-to-peak voltage of 0.1-10mV**, bandwidth **0.05Hz-200Hz**, **common mode voltages** (consists of 50-60Hz interference and DC electrode offset potential)

- ECG amplifier must have a **high common mode rejection ratio (CMMR), Low noise properties**, **High input impedance (about 5MW),***Very low input leakage current (below 1mA)*

- **AD620 Instrumentation amplifiers** and *OP07 low-power operational amplifiers* were used

Stage 1 — Pre Amp · Signal In · C_1 · R_1
Stage 2 — High-Pass Filter · R_{f1}
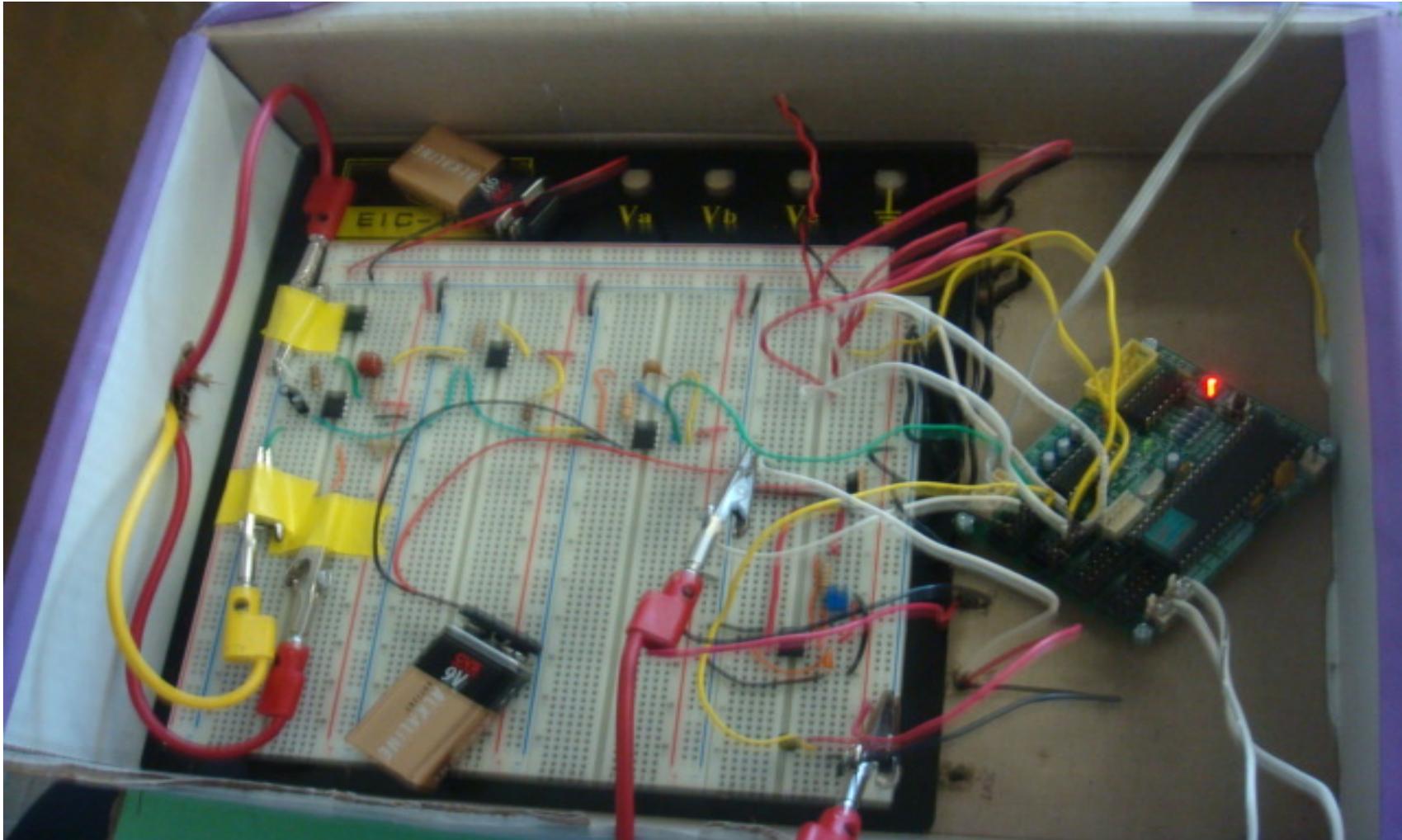Stage 3 — Low-Pass Filter · R_{f2} · C_2 · R_2 · Signal Out

ECG CIRCUIT and MEASUREMENT

- ECG signal amplified to ~1Vp-p

- Frequency 20Hz

- ECG signal responding to body movement (Vp-p at 1.435V)

- Alarming condition set when Vp-p is greater than 1.2V

INTEGRATED DESIGN:
Sensors | Microcontroller | Alarm

PERFORMANCE ANALYSIS

- System responds to a problem with the infant's position once 10 or more seconds have passed and infant has never returned to correct position

- ECG alarm condition is triggered once signal goes higher than 1.2 volts

- Temperature alarm condition is triggered once signal goes higher than 37.3ºC with +/-0.4ºC precision

- Buzzer goes off to alert when one or more alarm conditions have been met in the system

PERFORMANCE ANALYSIS Q&A

- What if the infant is 38.5⁰C and lying on its back?

- **Answer:** The temperature LED is turned on and the buzzer is turned on for a second and then turns back off. These steps repeat until the temperature falls back within the normal range.

PERFORMANCE ANALYSIS Q&A

- What if the infant is 38⁰C and it has not been on its back for 10 or more consecutive seconds.

- **Answer:** The temperature LED is turned on and the buzzer is turned on for a second and then turns back off. Next, the position LED is turned on and the buzzer is turned on for a second and then turns back off once again. These steps repeat themselves as long as the temperature does not fall back into the appropriate range and the infant remains off its back.

BUDGET

Components	Price	Justification
Infrared LED (4)	$5.28	Emitter to help monitor infant position
Photo IC Infrared (4)	$5.12	Receiver to help monitor infant position
LM 35 (5)	$8.70	Precision temperature sensor to measure infant temperature
Electrodes	$65.00	Helps monitor infant's heart rate
Electrode wires	$25.00	Helps monitor infant's heart rate
AD620 (2)	$19.88	Instrumentation IC amplifier for ECG circuit
OP07 (3)	$20.04	Low power IC amplifier for ECG circuit
Night-vision Camera	$45.00	Provides visual image of infant
Microprocessor	$50.00	Includes board, processor, and cables
Baby Mannequin	$20.00	Demonstration purposes only
Alarm System /Buzzer	$15.00	Used to alarm parents that infant is in SIDS prone condition
9V Batteries and clips	$30.00	Generates power to system
Miscellaneous Costs	$50.00	Resistors, Capacitors, Electrical tape, Heat shrink, etc
Shipping of products	$55.00	Most products were ordered online and had to be shipped
Total	**$414.02**	

CONCLUSION

- We have succeeded in designing a multi-sensor infant monitoring system with a temperature monitor, position monitor, ECG monitor, and video surveillance

- Our system will effectively detect multiple signals and vital signs that may help reduce the onset of SIDS

- To complete the project, we needed a working knowledge of various subjects such as:
  - Electronics, Network Analysis, Signals and Systems, Microcomputer Design, and Embedded Systems

FUTURE WORK / IMPROVEMENTS

- Make use of microcontroller timer modules and interrupt functions to produce a more reliable system response

- Find an easier way to effectively monitor the infant's resting position

- Add the necessary functionality to safely transmit wireless signals to a receiver that can be placed in caregiver's room for alarming purposes

- Use opto-isolators to reduce any backflow of current and voltage from sensors into microcontroller

THANK YOU!

- Questions

- Comments

- Concerns