Project Description:

EX500R Digital Instrumentation Display (Ninja DIdy)

By

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**Introduction**
The EX500R Digital Instrumentation Display (Ninja DIDy) is a digital instrumentation display for the Kawasaki Ninja EX500R motorcycle. The device will display key performance data, such as engine rotation speed (rotations per minute or RPM), vehicle travel speed (miles per hour or MPH), operating temperature, odometer (total distance traveled through the life of the vehicle) and trip odometer (distance traveled, which can be reset by the user). The device will also indicate the use of blinkers, high-beams and neutral gear engagement.

**Project Hardware and Applications**
The Ninja DIDy will replace the stock instrumentation cluster of the EX500R, providing the same vehicle performance data, yet the analog sensing methods and interface is replaced with digital systems. The device will also employ some of the existing electronic circuitry to detect certain parameters, such as turn signal activation. The user interface includes a 16 X 4 LCD display output and a push button for user input.

Figure 1 - Conceptual Sketch of Final Product
EX500R 12 Volt Instrumentation

Supy

Ignition Switch

Linear Voltage Regulator

Error

5V

Vcc

Vcc

Hall Effect Switch

Primary Ignition Coil

Temperature Sensor

A/D Converter

Comparator

Low Pass Filter

M8 MCU

PSOC CY829466

Control Button

16 Bit Counter

16 Bit Timer

16 Bit Timer II

Low Voltage Detect and Power On Reset

2K Flash

Internal Oscillator

P00

P01

P02

P04

P1 0-4

P2 0-7

XTAL in

XTAL out

External Crystal

L Turn Signal

R Turn Signal

High Beams

Neutral Gear

Voltage Converter

Voltage Converter

Voltage Converter

Voltage Converter

20 X 4 LCD Display

Figure 2 - Hardware Block Diagram
Detailed Hardware Description
Cypress PSoC CY8C29466
The CY8C29466 is a Programmable System on Chip, which includes an 8-bit Harvard Architecture Processor, 16 programmable digital blocks and 12 programmable analog blocks. The analog and digital blocks, structured as arrays, can be programmed for various peripheral functions such as digital communications and digital/analog conversion. The device is specified by the manufacturer for automotive applications.

The device also features 32K bytes of flash program memory, which will be used for EEPROM emulation, as well as 2K bytes of SRAM. The EEPROM emulation will be used to provide nonvolatile storage for the odometer and trip odometer data. The Ninja DIDy will use the 28-Pin DIP package of the CY8C29466 with 21 GPIO.

The device also features a low voltage detection circuit that creates an interrupt for the PSoC to reset. The Power On Reset will monitor Vcc until a tolerable level is found. An external crystal of 32.768 KHz will be used, in accordance with PSoC specifications, to guarantee precision clocking.

I believe this device is the best choice for this project at it incorporates so many of the necessary components for the Ninja DIDy, all of which are easily controlled by software.

Power Supply
An automotive power supply device, which provides protection against for transient and negative voltages must, be used. The automotive power supply will output the regulated 5-volt Vcc for all applicable components. The input voltage will be supplied by the EX500R’s unregulated 12 volt instrumentation supply, which is switched with the vehicle’s ignition switch.

The power supply will also have an error detection feature, which will detect drop in regulated voltage. This feature will be used to trigger an interrupt for the PSoC to execute shutdown functions when the device is being powered off. A capacitor and diode circuit will provide power to the PSoC during the shutdown routine.

The error detection feature will be used as opposed to the PSoC Low Voltage Detect feature to provide a higher threshold voltage at which the shutdown sequence will begin.

Ignition Pulse Detection
The first 16-bit timer module will time the period between rising edges of the ignition pulses from the primary ignition coil of the EX500R. These pulses will be inputted to the PSoC where a low pass filter module will filter the high frequency noise. Thereafter, the ignition pulses will be conditioned to digital pulses by a comparator module. The 12-volt ignition pulse will need to be lowered to less than 5-volts as to avoid exceeding the maximum input voltage of the PSoC.
The ignition pulse is currently wired directly to the stock instrumentation display. The Ninja DIDy will use this existing connection.

*Tire Rotation Sensing*

The second timer will time the period between pulses of the Hall effect sensor, mounted on the front suspension fork of the EX500R. A magnet mounted on the front wheel, adjacent to the Hall effect sensor, will trigger a voltage pulse corresponding to a full rotation of the front wheel. These pulses will be counted by a 16-bit counter module, as well as being timed by the 16-bit timer. This information will be converted to vehicle speed, as well as total distance traveled, in conjunction with the physical dimensions of the front wheel.

The Vcc, ground and output of the Hall effect sensor will run down the front suspension of the vehicle. Shrink tubing may be considered to manage and secure the wires.

*Engine Temperature Sensing*

EX500R temperature sensor is a thermistor, providing an impedance that varies with temperature. This change in impedance will be sensed as a change in voltage through a resistive divide. The PSoC 10-bit A/D converter module will convert sensor voltage to the vehicle’s current operating temperature.

*Control Button*

One single-pole, single-throw, momentary-on push-button switch will be connected to the PSoC GPIO pin as a user interface button, allowing the user to navigate settings of the device. The button will be panel mount and waterproof in design, allowing access on the outer surface of the Ninja DIDy’s enclosure.

*High-beam, Turn Signal and Neutral Gear Indicators*

The signals currently driving the high-beam, turn signal and neutral gear indicators of the EX500R stock instrumentation display will be connected to the PSoC through individual voltage converters (currently, these are 12-volt signals).

*LCD Character Display*

A 16 X 4 LCD character display module, with backlight, will be employed as user interface. The module will display the various parameters EX500R’s operating characteristics as chosen by the user. The display module will be connected to and controlled by the PSoC through a 7-bit bus.

The LCD display is of specific concern, as the water resistance of standard LCD character modules could not be found. In worst case, special insulating compounds, adhesives or film may be considered to water proof the final product. At this time, the
cost effectiveness of the LCD module is considered to outweigh the alternatives such as Vacuum Fluorescent Displays.

Enclosure
The Ninja DIDy will require an enclosure with the shape and dimensions specified in figure 1. The enclosure will need to be completely waterproof and able to withstand vibrations and inclement weather conditions.

Software Description
The PSoC microcontroller will be programmed using Cypress PSoC Designer V5.0. The programming will be composed in the C programming language. The C-code will be written in and compiled by PSoC Designer, which includes a C compiler produced by Hi-Tec. The program will be separated into several user modules.

The analog and digital blocks are defined within PSoC Designer, including settings such as clock source, interrupt type, sample rate, interrupt parameters, etc… They are also routed to various GPIO through PSoC Designer’s graphical user interface. Once defined, they are controlled with software by Application Programming Interface (API) functions.

Main
Upon startup, the PSoC M8 global interrupts will be enabled for the shutdown routine in which the odometer data will be stored in flash through the EEPROM API. Previously stored application data will be read from storage into applicable variables for modification. Also, all digital and analog user modules, including timer, counter and analog to digital converter and comparator will be enabled. The 16-bit counter used in the speedometer module is free running and will be started prior to the main loop.

The main function will then enter a continuous loop, consecutively executing each non-interrupt based module. The loop will be time-sliced, facilitating a refresh rate for the LCD that allows legibility by the user without compromising functionality, as the operational parameters of engine and vehicle speeds may change rapidly.

Tachometer
The Tachometer module monitors the input pin of the ignition pulse signal. When a pulse occurs, the pulse voltage will be detected by PSoC comparator module. The resulting pulse of the comparator will enable the 16-bit timer. The following pulse will cause the timer to stop and the application will read the current count of the timer and convert the data to RPM. The PSoC system clock will be divided down as a clock source for the timer.
**Speedometer**

The Speedometer module monitors the output of the Hall effect switch. When a pulse occurs, the second PSoC16-bit timer module will be started. The following pulse will cause the timer to stop and the application will read the current count of the timer and convert the data to MPH.

**Temperature**

The temperature routine will use the PSoC A/D converter to sample and convert the voltage of the temperature sensor into a corresponding digital value. The result will be interpreted to a temperature value through a lookup table.

**Shutdown**

When the device is powered off, the error pin of the power supply will drop low, triggering an interrupt for a shutdown routine. The shutdown routine will store the current display settings, odometer and trip-odometer data will be stored in flash memory via EEPROM API.

**High-beam, Turn Signal and Neutral Gear Indicators**

Each PSoC pin connected the indicator signals will be polled during each time-slice loop.

**LCD Routine**

The LCD routine will display all operating parameters based on the settings specified by the user, including:

- Tachometer reading in RPM
- Tachometer reading as a bar graph
- Speedometer reading in MPH
- Odometer Reading in miles
- Trip-odometer reading in miles
- Temperature bar graph
- High-beam indicator as letter B
- Turn signal indicator as letter L or R
- Neutral Indicator as letter N

The information to be displayed will be written to the LCD via PSoC API. The API implements the Hitachi HD44780 Display Driver Chip Protocol communicating with the LCD drivers onboard the LCD module.

**Settings**
Pressing the push button will result in a routine wherein the user can change the current display parameters (see figure 3). Holding down the button for 3 seconds will cause the trip odometer to be reset.

Figure 3 - Software State Diagram

Development Plan
Winter and spring quarters of the 2008-2009 school year will be used to complete the Ninja DIDy. Winter quarter will be focused on completing hardware design and testing with some software development. Spring quarter will focus mainly on software development and final product debugging, as well as preparing deliverables and presentations for hardware and software systems as requirement for ETEC 474.

*Weekly Schedule: Winter Quarter*

All remaining input signals from the EX500R will be analyzed and documented in detail. This will allow for completion of hardware design including the placement and values of passive components that may be necessary to bias the active ICs. Once the hardware design is complete, an order will be placed for the parts.

While the parts are received and verified, a more detailed conceptual design of the software will take place with composition of flowcharts and diagrams that specify the all necessary algorithms.

Each hardware component will then be tested individually, except the PSoC. Following testing of the hardware components, the layout of the PSoC modules will take place; each necessary analog and digital device will be defined, with operational parameters, within PSoC Designer.

Very simple I/O programs, in conjunction with all peripheral components will be used to test the functionality of all hardware components, including the PSoC’s analog and digital modules. Next, software coding and debugging will begin.

<table>
<thead>
<tr>
<th>Week</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Complete analysis of all signals from the EX500R (ignition pulse waveform, temp sensor voltage)</td>
</tr>
<tr>
<td>2</td>
<td>Complete design of circuitry such as external passive components for biasing</td>
</tr>
<tr>
<td>4</td>
<td>Design software flow charts and detail algorithms</td>
</tr>
<tr>
<td>5</td>
<td>Design software flow charts and detail algorithms</td>
</tr>
<tr>
<td>6</td>
<td>Construct and test function of power supply</td>
</tr>
<tr>
<td>7</td>
<td>Test remaining components including comparator, reference voltage and LCD</td>
</tr>
<tr>
<td>8</td>
<td>Begin layout of PSoC array design and device settings</td>
</tr>
<tr>
<td>9</td>
<td>Complete design of PSoC arrays including all GPIO, interrupt and device parameters</td>
</tr>
<tr>
<td>10</td>
<td>Test operation of components together, such as proper transfer of signals with PSoC</td>
</tr>
<tr>
<td>11</td>
<td>Software coding and debug: start up and primary loop</td>
</tr>
<tr>
<td>12</td>
<td>Software coding and debug: LCD module</td>
</tr>
</tbody>
</table>

Winter Quarter Schedule
Spring Quarter
Spring quarter will mainly be software development. Once all the modules and header are complete, the demonstration product will be assembled and tested in its entirety with the EX500R.

<table>
<thead>
<tr>
<th>Week</th>
<th>Task</th>
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<tbody>
<tr>
<td>1</td>
<td>Software coding and debug: speedometer and tachometer</td>
</tr>
<tr>
<td>2</td>
<td>Software coding and debug: tachometer and shutdown routine</td>
</tr>
<tr>
<td>3</td>
<td>Prepare ETEC 474 hardware review and written documents</td>
</tr>
<tr>
<td>4</td>
<td>Complete ETEC 474 hardware review</td>
</tr>
<tr>
<td>5</td>
<td>Complete ETEC 474 hardware documentation</td>
</tr>
<tr>
<td>6</td>
<td>Prepare and present software systems for ETEC 474</td>
</tr>
<tr>
<td>7</td>
<td>Software coding and debug: all remaining modules</td>
</tr>
<tr>
<td>8</td>
<td>Software coding and debug: finalize</td>
</tr>
<tr>
<td>9</td>
<td>Prepare for ETEC 474 code review and perform final test</td>
</tr>
<tr>
<td>10</td>
<td>Complete final test, build and present final product</td>
</tr>
</tbody>
</table>

Spring Quarter Schedule

Development Resources
PSOC Designer 5.0 and PSoC Programmer 3.0 will be required for programming the PSoC analog arrays, digital arrays and microcontroller. In conjunction, the PSoC In Circuit Emulator (ICE) and PSoC Mini Prog device will be used to debug and program the software.

The PSoC EVAL 1 board will be used for hardware development, along with additional bread board space for all components. The PSoC EVAL1 board provides a header for LCD module attachment, as well as a push button, which will allow convenient testing of the LCD display routine. The debug pod or PSoC can be programmed from a PC by the PSoC Mini Prog via USB. The smaller bread board of the PSoC Eval 1 board will require an additional bread board to be used in development.

Additional test equipment required:
- Bench voltage supply
- Oscilloscope (portable to connect to the EX500R outside of lab space)
- Function Generator
- Multimeter (with frequency counter)
- LC Bridge
• PC with development software

**Demonstration Prototype and Materials**
The PSoC Eval 1 development board will be used to demonstrate a prototype of the final product. All peripheral hardware will be connected using a pre-punched perforated board and soldered with wires. An ABS project enclosure may be used for presentation, with the LCD and push button mounted externally.

As the Ninja DIDy operates with the EX500R motorcycle, the prototype will be connected to the EX500R and its operation will be documented by a video recorder and displayed during presentation. The demonstration prototype will also be available for inspection.

**Sustainability Design Issues**
As the existing stock instrumentation display uses small incandescent lamps to laminate the display and indicators, the Ninja DIDy will dissipate much less energy.

Soldering flux is the only hazardous materials that will be used in developing this project. No waste issues are of significance.

**Electrical Specifications**

**Project Specifications**

<table>
<thead>
<tr>
<th></th>
<th>Tachometer (RPM)</th>
<th>Speedometer (MPH)</th>
<th>Temperature (°F)</th>
<th>Odometer &amp; Trip (miles)</th>
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<tr>
<td>Accuracy</td>
<td>+/- 25</td>
<td>+/- 1</td>
<td>+/-10</td>
<td>+/- .1%</td>
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<tr>
<td>Resolution</td>
<td>25</td>
<td>1</td>
<td>10</td>
<td>0.1</td>
</tr>
<tr>
<td>Range</td>
<td>60 – 12000</td>
<td>0- 120</td>
<td>0 - 182</td>
<td>0 - 1,000,000</td>
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**PCB Size Limits**

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<tr>
<th></th>
<th>Length (cm)</th>
<th>Height (cm)</th>
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<td>10</td>
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**Environmental Specifications**

<table>
<thead>
<tr>
<th></th>
<th>Operating Temperature (°C)</th>
<th>-30 min</th>
<th>-40max</th>
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<tbody>
<tr>
<td>Others</td>
<td>High frequency mechanical vibrations (approx 6 kHz)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inclement weather including rain, show and high humidity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Preliminary Parts List

<table>
<thead>
<tr>
<th>Device</th>
<th>Model</th>
<th>Total Cost</th>
<th>Qty</th>
<th>Lead Time</th>
<th>Power Dissipation (mW)</th>
<th>Source</th>
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<tbody>
<tr>
<td>PSoc</td>
<td>CY8C29466</td>
<td>$8.78</td>
<td>1</td>
<td>1 week (delivery time)</td>
<td>49.5</td>
<td><a href="http://www.digikey.com">www.digikey.com</a></td>
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<tr>
<td>LCD Module (16X4)</td>
<td>NHD-0416BZ-NSW-BBW</td>
<td>$19.10</td>
<td>1</td>
<td>1 week (delivery time)</td>
<td>8.25</td>
<td><a href="http://www.digikey.com">www.digikey.com</a></td>
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<tr>
<td>Voltage Regulator</td>
<td>LP2957</td>
<td>$7.70</td>
<td>5</td>
<td>1 week (delivery time)</td>
<td>21</td>
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<td>Hall Effect Switch</td>
<td>AH 182</td>
<td>$1.55</td>
<td>1</td>
<td>1 week (delivery time)</td>
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<tr>
<td>Push Button Switch</td>
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<td>Crystal (32.768 KHz)</td>
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<td>Diode</td>
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<td>1 week (delivery time)</td>
<td></td>
<td><a href="http://www.digikey.com">www.digikey.com</a></td>
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