Tethys LRAUV
Load Control System
Description (Draft)

28 May 09	ecm	initial draft
8 Jun 09	ecm	revise to released board spec
5 Nov 10	ecm	revise to 3.1

Summary

The Load Control System distributes and controls serial I/O and power to peripheral devices within the Tethys vehicle. The overall system consists of up to four 8-slot Backplanes, each containing up to eight Load Control Boards (total 32). The vehicle main computer communicates with the Load Control Boards (LCBs) via SPI (Serial Peripheral Interconnect). The vehicle Motherboard supplies bulk DC power for distribution, at nominal voltages of 3.3, 5, 12, 24, and Raw Battery (12-17V).

Each LCB contains a UART, level shifters for RS-232 or RS-485, and a power switch with soft start, circuit breaker, and isolation functions. Each board is configured at assembly time for one of three serial formats and one of the five power distribution voltages. A PIC microcontroller on each board operates the power switch section based on commands from the main vehicle computer, and returns telemetry of current, voltage, and switch state. Individual peripheral devices throughout the vehicle plug into output connectors on each LCB to receive switched power and serial comms.

The Load Control System is designed with micropower operation as a design priority, and operates in standby (power on, no serial traffic) on a few mW per channel.

Specifications

Power Voltages:	Nominally 3.3V, 5V, 12V, Raw Battery (10-17V), and 24V (any combination up to five voltages can be configured)
Current Rating:	3A; nominal 2.7A current limit
On Resistance:	0.05 ohm
Circuit Breaker:	Hardware current limit at 2.7A Hardware circuit breaker after 70 msec in current limit Sortware circuit breaker with (TBD) scan times Separate Peak and Average trip values 5A fuse
Soft Start:	Load inrush charge 0.2 Coulomb max (approx) e.g. up to 6800 uF at 24V, up to 33,000 uF at 5V, etc
Isolation:	dual coil latching relays DPST power, 4PST comms
Serial Comms:	9600 - 115k bits/sec RS-232, RS485, or TTL (configuration option)
Telemetry:	0 - 4A, 0 - 25V, 10 bit resolution Switch Closed, CB Tripped, and Output-On flags
Board Power:	3.3V logic supply @ ~1 mA 3.3V serial-comms supply, current depends on serial format

12V or raw battery supply, 25 mA for 10 msec (relay coils)
Power switch circuit draws 0.25 mA from power rail when active

Dimensions: 5”w x 2”h x 0.45”t, fits 0.5” backplane pitch

Description

1) Power Switch

a) Switch/Current Limiter:

The core of the power switch is the current-limit circuit formed by Q7, U8, and R3. The current-limit level is set by the voltage on U8’s (+) input, which in turn is set by drawing a small command current from the positive rail, through R20, and down through Q2.

The R26/R21 divider establishes a millivolt-level bias, in the Off direction, that overcomes any offset in U8 and guarantees that U8’s output swings high (Q7 turned hard off) when the current command is zero. Zener D15 protects Q7’s gate, and C13/R24 compensate Q7’s gate capacitance.

b) Current Command

The current command sets the current limit of the main switch Q7. The command current is drawn by Q2 and R16, in proportion to the input voltage on Q2’s base. In the simplest case this input is a 0V/3.3V logic signal that turns the main switch either off, or on with a 2.7A current limit. This input can also be varied linearly to generate a programmable current limit, in which case R13 and C11 can serve as a lowpass filter for a >1kHz PWM signal.

c) Phantom Ground:

The power switch is designed to work with power voltages between 3.3V and 24V (or higher, with suitable choice of Q7). To accommodate this wide range, the power switch circuits (eg U6-7-8) all draw operating current from the positive rail, and return it to a ‘phantom ground’ rail that is held 7.5 volts below the positive rail. This ‘ground’ current then flows through Q1 and down to actual ground via Q3. This arrangement provides a controlled, low impedance gate swing for Q7 (via U8), and a low voltage environment for the rest of the power switch circuits, regardless of power voltage. As an incidental feature, the power switch circuits can be powered down completely by opening Q3, which allows the phantom ground rail to drift upward to the positive rail, and reduces overall consumption from 250uA to <1 uA.

The phantom ground’s voltage is regulated by Q1. For power voltages greater than 10V, and assuming Q3 is on, D4 and R10 hold the gate of Q1 at 10V below the input rail. Q1 then turns on any time the phantom ground rail rises Vgs(th) (about 2.5V) above this (which is 7.5V below the positive rail), and conducts phantom ground current down to the common rail. Q1 transconductance is high enough to keep Vphantom within a few tenths of a volt even with milliamps of current flowing, such as during Q7 gate excursions.

For power voltages of 3.3V or 5V, the phantom ground is not required and the switch circuits can operate between the positive rail and the power common rail. This is accomplished by bypassing Q1 with JMP2.

d) Current Sense

Shunt R3 generates the feedback signal for current limit amplifier U8. The shunt’s voltage is also used to drive current sense amplifier U7. R25 and Q5 convert the sense voltage into a current signal with a nominal value of 10uA per amp. Q5 also translates the signal down to the common rail, where it is scaled to a voltage by R15 and then buffered by U3. C10 provides lowpass filtering and R18 limits fault current which could flow from the positive rail through R25, Q5, and U3 (via ESD diodes) onto the logic supply LCB3.3+.

e) Current-Limit Detect

During normal operation the power switch Q7 is either off or fully on, and U8's rail-to-rail output swings Q7's gate all the way to either the positive or phantom ground rails. When load current reaches the current-limit setpoint, U8 drives Q7 into the linear region, with gate voltage typically 3V below the positive rail. Q7 will overheat rapidly in this condition (potentially dissipating as much as Vin x Ilim). To signal this condition, comparator U6 triggers anytime Q7's gate is not within 0.25V of the phantom ground rail (i.e. anytime Q7 is not fully on). U6 drives Q6 which drives current through R14 to generate the CL_Active logic signal, limited to 3V by zener D11. The microprocessor should respond to CL_Active by turning off SwitchOnCurrent within 50-75 msec, to limit the temperature rise of Q7 to survivable levels.

f) Discussion

The LT6003 op amps used for current sense and current limit detect are ~2uA devices that are very slow (2 KHz GBW, 0.2V/msec SR). If more speed is needed for any of these functions, the LT6000 should be able to drop in and provide 10x speed, at the cost of 10x supply current.

The "floating" switch section, which operates referenced to the positive rail, is interfaced to logic and power common by high-voltage devices (Q1, Q2, Q3, Q5, Q6). With a suitable choice for Q7 (and possible re-scaling of R10), this should allow the switch circuit to operate to at least 48V, and possibly quite a bit higher.

The input current command (SwitchOnCurrent) and current sense output (CurrSense) functions are subject to offset and gain errors, due to several 1% resistors, op amp offsets, etc. For best accuracy these errors can be calibrated out by checking at (say) 10% and 90% of full scale, and storing correction values in the microprocessor.

2) Serial Comms

3) Discrete I/O

4) Microcontroller and Bus Interface

5) Assembly and Configuration