LRAUV Motorized VB Valve Drive
Design Notes

11 Mar 13 ecm update from redlines; add component ref numbers to Approach section

Requirements:

1. Input power 10-24 VDC, switched by LCB

2. Drive Maxon 221024 motor plus 110340 gear (370:1)

   5V nom, 2.2 ohm winding
   2.3A stall current @ 5V
   0.6A run current @ predicted valve load (Jon's analysis 4/11/2011)
   0.8A max continuous current (Maxon spec, thermal limit)
   predicted quarter turn time 1.3 sec @ 5V with predicted valve load

3. Accept input command from EZServo 'On/Off' output. (switched Battery voltage)
   Level triggered:

   "Off" --> Close Valve (also EZServo power down state, and initialized state after POR)
   "On" --> Open Valve

4. Close valve automatically, using stored energy, if power fails. (Worst case is immediately after opening.)

5. Accept input from PSW-500 pressure switch. Force valve to Closed state, and do not allow Open command, below switch actuation depth.

Additional Features:

6. "Ready" output when enough energy is stored for operation and all supplies are within tolerance.

7. "Closed/Open" output to verify valve position

Approach:

1. Micropower DC-DC U1 charges supercapacitor C7-C8 to 5 V.

2. Motor Drive system runs on 5 V. H-Bridge U3 controls motor Forward and Reverse motion. Features: Micropower Idle state; UV Lockout below 2.3 V; Output current limit 2.8 A; Possible soft-start ramp (not implemented, motor starts from stall). Possible braking function (not implemented, motor coasts to stop).

3. Magnets on valve shaft trigger Hall sensors U12 and U16 on Drive Board. Hall sensor feedback terminates movement at either end of valve travel, also generates ‘Opened’ output signal that indicates opened/closed status.

4. Discrete logic combines input and feedback signals, generates motor RunFwd and RunRev commands.

5. DC-DC U1 is current limited to ~0.6 A by choice of resistor R4. 0.6 A allows motor to run

at predicted torque indefinitely without discharging supercap, or stall indefinitely without overheating. 0.6 A will take 21 seconds to charge supercap (2.5F) from 0 to 5 V during a cold start.

6. Typical 1/4-turn move takes 1.3 seconds at 0.6 A run current (Jon's prediction). This runs supercap down by 0.3 V. Worst-case 1/4-turn move takes 2 seconds at 1.0 A run current (Ed's WAG). This runs supercap down by 0.8 V. Motor stall takes 2.3 A peak, supercap discharges to 1.3V with RC time constant of 5.5 seconds at which point motor current will be the 0.6 A supplied by the current-limited DC-DC converter.

7. Voltage Monitor/Supervisor U7 generates the Fault signal if input power is <10V, motor drive 5 V power is <4.5 V, logic power is <3 V, or the TooDeep signal has been asserted by the external pressure switch. The Fault signal drives the motor to the Closed position, and de-asserts the Ready signal.

8. 'Ready' output status signal is asserted when all supplies are above minimum limits, pressure switch does not signal TooDeep, and valve actual position agrees with commanded position.

9. Micropower low-dropout (LDO) linear regulator U5 generates 3.3V logic supply, from either input power (10-24V) or from 5V motor power (diode-OR).

10. With input power removed, all logic circuits will remain powered by 5V bus from supercap. Current drain at room temperature or below should be 20-30 uA. Supercap will supply this current for about 8 hours before discharging to 4.5 V undervolt threshold, thus should be instantly ready for action if VB has been used anytime in previous 8 hours.

11. Test jumper JMP1 is provided to assert the OpenReq signal, which drives the valve open for test/maintenance purposes if no faults exist. Test jumper JMP2 is provided to discharge the supercaps before the board is handled or reworked, or while stored. Bleeder R24 has a 1-min time constant and needs about 5 minutes to discharge the caps below 1% of initial value. *Both jumpers must be removed when the vehicle is in an operational state.*

Design Notes

1. Input clamp zener D2 rated 30V breakdown, 24V standoff. Input anti-reverse diode D1 blocks a conduction path from the 5V rail back thru the DC-DC converter U1 and out the input.

2. DC-DC U1 current limit is affected by:
    a. Resistor on SS pin, which programs nominal peak current limit
    b. Input/output voltage ratio, which affects peak current limit by 30-40%
    c. Inductor value, which affects delta-i and peak/average ratio

    Overload (stall) current is not badly affected by input voltage… seems safe to set this to 0.7A into 2.2 ohms with 15V input, by selection of SS resistor. This should protect motor and account for chip and inductor variability, then let other operating points vary.

3. DC-DC U1 Rt = 35.7k programs 1 MHz clock, should allow 8% - 85% duty cycle.

4. Inductor L1 needs min value around 5uH (at low tolerance and drift) to control delta-I and to avoid "running dry" at low line/full output condition. Higher inductance gives lower delta-i and lower peak current. Coilcraft loss calculator shows core loss dominant, pushes L higher at expense of R… losses equal around 15-18uH.

5. Input filtering: CM choke L2 for CM noise from DC-DC and motor PWM. Single bead at input to keep local DM noise in, external DM noise out. Important to have minimal impedance (no filtering) between 5Com net and 3.3Com net, to prevent ground bounce and resulting logic noise.

6. Input caps C2, C3: largest value available at 50V in 1210 package, has compliant terminals ("Boardflex") for better reliability. C11 uses same part for commonality.

7. R10/R12 divider for 3.3 Undervolt: 2.1 uA @ 3.3V. Filter 0.1uF gives 13 msec time const.

8. R14/R15 divider for Batt Undervolt: Using 1.00M for commonality, 42.2k gives 1.2% error so actual threshold will be 9.88V. Divider current 9.5 uA. Filter 1uF gives ~40 msec time const.

9. Known loss sources when standing by on supercap charge, worst-case values:

    a. C6/C7 Supercap leakage spec 8 uA
    b. Supercap balance divider R1/R5 3 uA
    c. Supercap balance amp U4 1 uA
    d. U1 LT3991 Buck Regulator Iq 3 uA
    e. Schottky D3 leakage @ 5V 1 uA
    f. U1 PG output sinking when inactive (R10 pullup) 3 uA
    g. U5 LT3008 LDO Regulator Iq 6 uA
    h. R10/R12 divider for 3.3 Undervolt 2 uA
    i. U7 LTC2934 Iq 1 uA
    j. U7 RST_N or PFO_N output sinking when active (R13 pullup) 10 uA
    k. R16 Pressure Switch pullup 3 uA
    l. Hall Sensor SL353LT U12+U16 operating, 2 ea. 10 uA
    m. U3 Motor Driver standby 10 uA ?
    n. 74AUP1G99 gate standby 5 ea 3 uA ?
    o. 74LVC123 standby 10 uA ?

    Allow standby discharge from 5.0 to 4.8V to maintain 0.3V margin above 4.5V undervolt; this allows a valve move directly after power-up. Target 3 hr standby. 2.5 F x 0.2 V = 0.5 C charge. 0.5 C/10800 sec = 46 uA allowable leakage.

10. Other standby losses:
    a. R14/R15 Batt Undervolt divider 15 uA

11. R19 – Opto U11 LED current for OPEN Command = ~0.25 mA @ 10V. R26 added to desensitize U11 against microamp-level leakage from external Open Command driver… at least 50 uA required, 100 uA recommended.

Issues to Discuss

1. Interface signals:
    a. Level-triggered 'Open/Close' OK?
    b. Ability to read/react to Ready status

2. Power-up time:
    a. 20 sec from cold power-up until 'Ready'.
    b. Instantly ready after up to 3 hours Off time, thereafter 1 sec per hour wait time.

3. Connectors:

a. OK to combine separate devices in a connector, e.g. Input Power + Motor in the 'Power' connector, and Pressure Switch + Valve Open in the 'Signals' connector?
b. Molex 'C-Grid' for Signals connector, Tyco Micro Mate-N-Lok for Power connector

Checkout

1. Effect of temperature on current limit
2. Motor coasting distance

Fixes

1. Voltage Supervisor U7 push-pull outputs conflict due to wire-OR. Change U7 from -2 version to -1 (open drain) version. Add 330k (5 % 0603) pullup between pins 5+6, and 3.3V plane.

2. Need spy resistor for 3.3V supply. Cut trace between D8+D7 cathodes and U5 pins 1+5. Add 10 ohm (1%, 0603) resistor.

3. Test points on 5Com and 3.3Com ground planes?

4. Swap output signals (pin 2) from Hall Sensors U12 and U16.

5. Add "Discharge" jumper for 5V supercap bus. 51 ohm 1W 2512, 10 min to 1% charge.

6. Keep-out areas top side, non-round posts