AN1678

Automotive Relay Replacement Evaluation Board

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An Automotive Relay Replacement Board driven by an HC11 microprocessor is presented here. It is intended to run lamps and solenoids in an automotive environment with nominal voltages in the range of 12 V.

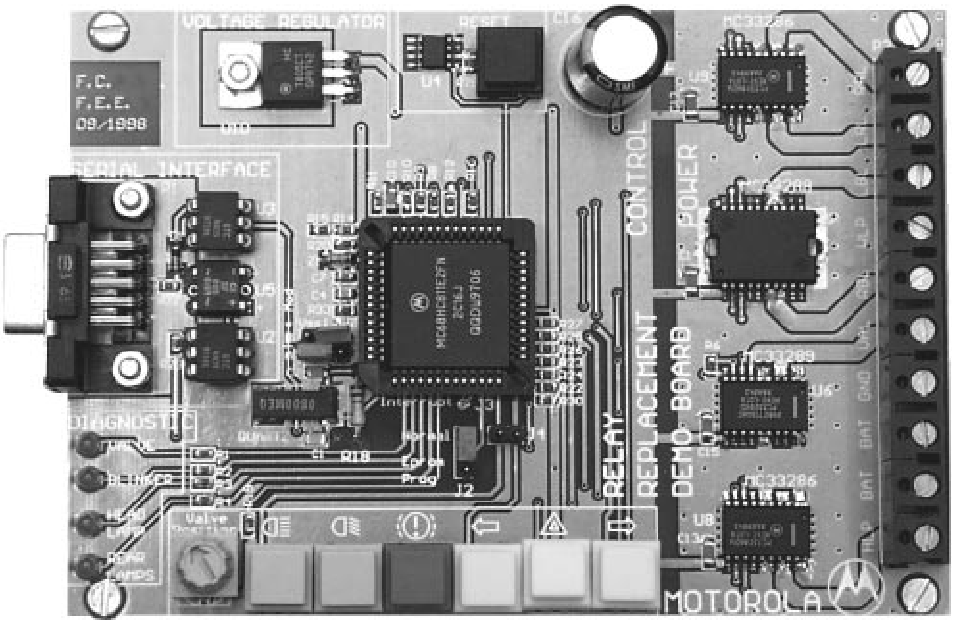

Figure 1. Relay Replacement Evaluation Board

INTRODUCTION

The penetration of electronics in the automotive industry started some 15 years ago with electronically controlled powertrain systems, mainly driven by regulatory legislation. Today, occupant safety is enhanced with ABS systems and airbags requiring even more complex electronics.

This penetration is still growing as we see the rise of another wave of electronics driven by consumers willing to personalize their daily driving experience in 3 key areas: comfort, security and driver identification. These areas require components with high reliability, new features, diagnostic functions, etc., but these changes require vehicle architecture modification as well as load control improvement.

Mechanical relays are unable to perform certain desired functions such as soft turn on and turn off of motors, or dimming of incandescent loads. Improvement in semiconductor technologies and in package development now make possible a conversion from a mechanical relay to an electronic driver which can offer more functionality, higher reliability and system cost reduction.

Features like current limitation can be implemented easily on an electronic relay, allowing fuse elimination and wiring diameter reduction. Self–protection such as short circuit shutdown or over–temperature shutdown increase the reliability of the relay, and diagnostic functions such as open load detection let the user know when the load is disconnected or damaged.

Other advantages of the electronic relay over the mechanical relay are its smaller size, reduced weight and the elimination of acoustic noise. Electronic relays generate less heat than mechanical relays.

The Automotive Relay Replacement Board shown in Figure 1 was developed to demonstrate and evaluate members of a new product family designed to replace mechanical relays.

EVALUATION BOARD DESCRIPTION

Overview

The evaluation board is designed to drive automotive bulbs and solenoids. It is controlled by an HC11 microprocessor that can be programmed via an on board serial interface. The microcontroller delivered with the board is pre–programmed but can be re–programmed from a PC with the help of software. The user can select the different loads with the buttons at the bottom of the board — see Figure 2.

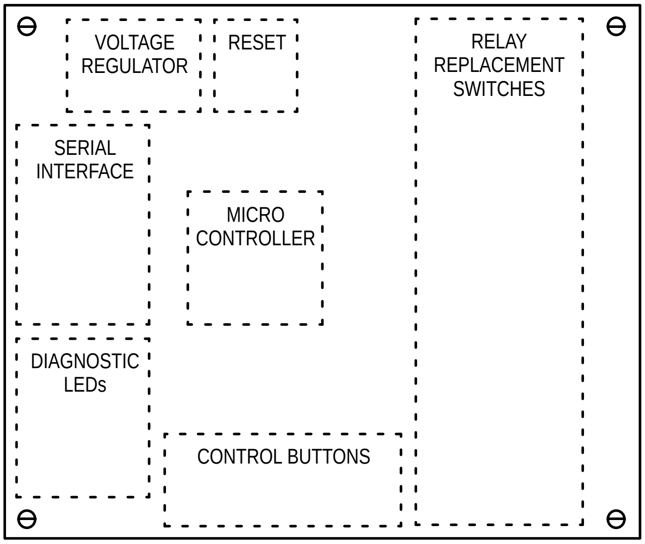

Figure 2. Evaluation Board Functions

The relay replacement drivers are on the right side of the board — the Power Stage. They are surface mount Integrated Circuits soldered directly onto the PCB.

Power Stage Description

Three different products used in the Power stage are relay replacement dual high side drivers, namely:

- 2 MC33286DW: GEMINI
- 1 MC33288DH: FLASHER
- 1 MC33289DW: DHSS

Each IC contains 2 silicon chips: a control die and a dual power die. The power die is a MOSFET with the drain connected to the Vbat line. The Source of the MOSFET is connected directly to the load.

The heat generated by the ICs is dissipated via the PCB copper traces connected to the Vbat line. The total Vbat copper traces surface for the 4 products is close to 36 cm^2.

Following is a short description of each of the products.

GEMINI: Dual High Side Driver for 21W bulb. The GEMINI has the following features:

- 35 mΩ Rdson max. at 25°C
- Breakdown Voltage greater than 40 V
- Current limitation
- Open load detection in the On state
- Overtemperature shutdown with hysteresis
- Under voltage shutdown
- Separate diagnostic output
- Reverse battery protection
- Very low standby current (less than 1 µA)

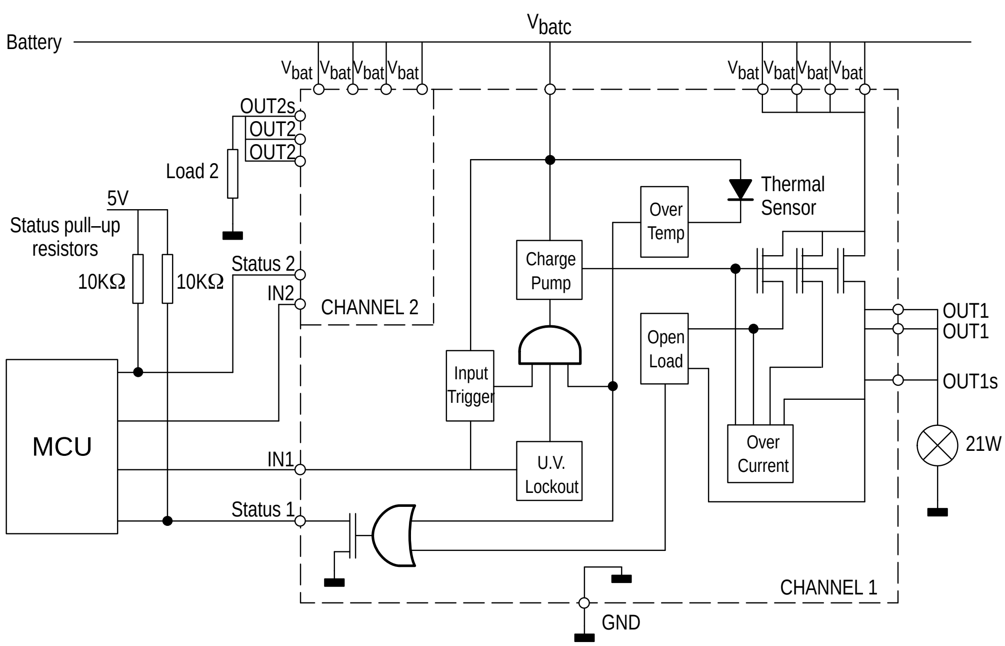

Figure 3. GEMINI Application Block Diagram

The GEMINI package is an SO20WB with a thermally enhanced leadframe to enable maximum power dissipation through the 8 leads that are connected to Vbat copper traces.

On the evaluation board, two GEMINI are used. The first one is used to drive two 21W rear lamps. The second GEMINI is used to drive a single 55W head–lamp with its dual output transistor channels configured in parallel.

FLASHER: Dual Solid State Relay for Blinker Applications. The FLASHER has the following features:

- 25 mΩ Rdson max. at 25°C
- 1.2W per channel Warning lamp Driver
- Breakdown Voltage greater than 40 V
- Current limitation
- Current recopy function
- Open load detection in the On state
- Overtemperature shutdown with hysteresis
- Under–voltage shutdown
- Common diagnostic output
- Reverse battery protection
- Low standby current (less than 5 µA)

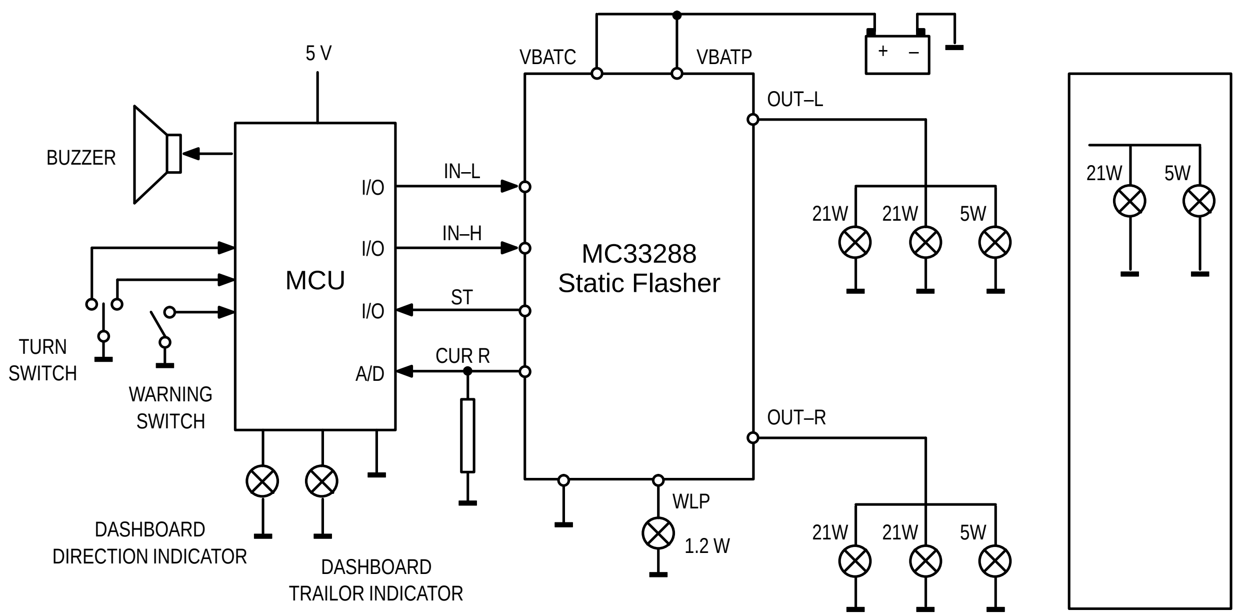

Figure 4. FLASHER Application Block Diagram

The FLASHER package is an HSOP20 with a copper heatsink. The thermal resistance from Junction to Case is as low as 2°C/W. On the evaluation board the thermal resistance from junction to ambient is lower than 25°C/W, which permits three 21W plus two 5W bulbs to be driven by each channel.

DHSS: Dual High Side Switch for inductive loads such as solenoid valves. The DHSS has the following features:

- 40 mΩ Rdson max. at 25°C
- Breakdown Voltage greater than 40 V
- Latched Current limitation
- Open load detection in the Off state
- Overtemperature shutdown with hysteresis
- Under–voltage shutdown
- Separate diagnostic output
- Reverse battery protection
- Very low standby current (less than 5 µA)

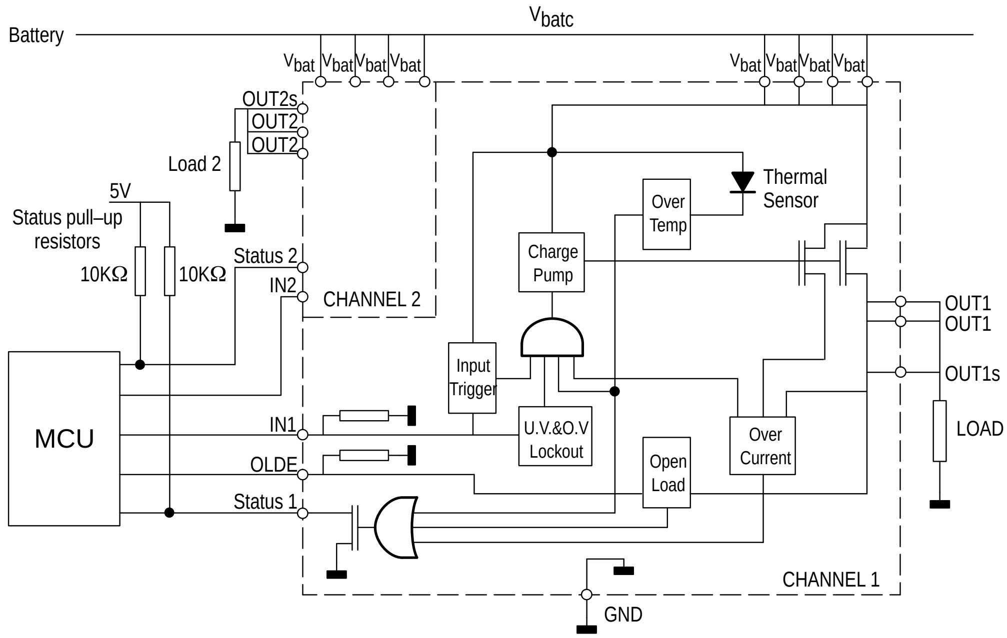

Figure 5. DHSS Application Block Diagram

The DHSS is in an SO20WB package. On the evaluation board, one output channel of the DHSS is used to drive a solenoid valve.

Control Stage Description

The control of the power products is performed with an MC68HC811E2 microcontroller. This microprocessor receives the user's commands through the push buttons and the potentiometer, then processes the information and provides the control signals to the power devices.

The microcontroller sends a 2 KHz PWM signal to the DHSS to control the valve. The position of the valve is a function of the duty cycle applied to the signal. The user controls the duty cycle with the potentiometer on the left side of the control switch panel.

The microprocessor also generates the low PWM frequency for the blinker and the rear lamps. The blinker frequency is 1.5 Hz with a 50% duty cycle. For the 21W rear lamps, a 100 Hz PWM frequency (undetectable to the human eye) is used with a 25% duty cycle to simulate a 5W bulb. During braking, the GEMINI turns the 21W rear bulbs on continuously.

Finally, the control stage scans the status output of each driver. If any problem appears, the LED corresponding to the failed device is turned on. For the blinker function, a complex "failed lamp detection" that is detailed below is implemented based on the current recopy function of the FLASHER device.

The DHSS fault detection latches off the faulted output. To get the DHSS to function again, just press the RESET button located in the top central area of the board.

For one second following the RESET, the FLASHER device is turned on to calibrate the "failed lamp detection" function. If no load is connected to the FLASHER output, it will detect an open load, and the fault LED will be turned on.

Programming the Microcontroller

As mentioned above, a serial interface was implemented on the evaluation board so that you can modify the program or write your own program to control the power devices. Along with the board a floppy disk entitled “Relay Replacement Evaluation Board Program” is supplied. It contains the source code and the files necessary to down load the program from the PC to the microcontroller.

You will need a PC with WINDOWS 3.11 operating system and the PCBUG11 software, a power supply (12 volts/15 Amps), and an RS232 cable to link the computer to the board in order to establish the communication. To download the software:

1. Connect the power supply and the RS232 cable to the board using the instructions given in the next section titled “Connector pin to pin description” (Make sure that there is no other application working on the port selected)
2. Put the microprocessor in the Bootstrap mode — this means MODA and MODB wired to Vss.
3. Turn on the power supply and press the RESET button.
4. Then start PCBUG11 up with the command: pcbug11.exe
5. Choose the appropriate options to configure the microprocessor:
   — Talker: no
   — XIRQ interrupt: no
   — Choice of the microprocessor: 4
   — Program directly a macro: no
   — Port used for the application: (1 or 2)
   — Internal clock 8 MHz: yes
6. If the communication is correctly established you are now ready to program the microprocessor. If there is no communication between the computer and the evaluation board, verify the instructions were performed in the right order. Check the RS232 cable connection on the board side (pins 4 and 7 should be +10 V and –10 V respectively) and then type “restart” in the command window of PCBUG11. Be careful: There must be no other application running on the port chosen for the communication. If there is still no response after doing this, turn off your computer and try again.
7. To start downloading the program, type the following instructions:
   eeprom $f800 $ffff
   loads a:\relay.map
   loads a:\relay.s19
8. To execute the program, put the switches back to their original position: MODA wired to Vss and MODB to Vdd.

Connector Pin to Pin Description

The power supply and all the loads can be hooked up to the evaluation board via the screw connector on the right side of the board.

BAT: Vbat supply voltage source input. All the power devices are connected to the Vbat rail, which corresponds to the battery voltage in the automotive application. Two screw connectors are used for the Vbat line due to the high peak currents during lamp inrush current. The nominal current when all products are running fully loaded is around 15 A. Transient current can reach up to 50 or 60 A. A 470 μF capacitor (C16) is placed between the Vbat rail and the Ground rail and allows up to 10m of wire connection between the evaluation board and the actual Vbat power supply in most of the test configurations. The microcontroller is also supplied by the Vbat rail through a 5 V voltage regulator on the top left side of the board.

GND: The Ground is common to the controller ground and the control pins of the power devices. No high current should normally flow through the GND except during the free–wheeling period of the valve when the DHSS is on.

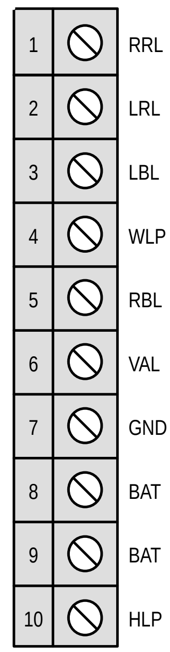

Figure 6. Connector Pinout

RRL: Right Rear Lamp. A 21W bulb can be connected to this output. This output is driven by the GEMINI right side (U9).

LRL: Left Rear Lamp. A 21W bulb can be connected to this output, which is driven by the GEMINI left side (U9).

RBL: Right Blinker Lamp. Three 21W bulbs and two 5W bulbs can be connected to this output (Car + Trailor). This output is driven by the FLASHER right side (U7).

LBL: Left Blinker Lamp. Three 21W bulbs and two 5W bulbs can be connected to this output (Car + Trailor). This output is driven by the FLASHER left side (U7).

WLP: Warning Lamp. A 1.2W dash board lamp can be connected to this output. It is turned on during the warning mode. This output is driven by the FLASHER Wlp output (U7).

HLP: Head Lamp. A 55W lamp is to be connected to this output which is driven by the two paralleled outputs of the GEMINI (U8).

VAL: Valve. The DHSS (U6) can drive an automotive valve with a nominal current of 1 to 2 A.

Jumper Description

J1: This jumpers is used to determine the mode of the application: single ship mode if we want to execute the program, and bootstrap mode to program the microprocessor.

J2: This is linked to the XIRQ* pin and is only used for the external interrupts.

J3: This jumper is linked to the IRQ* pin and it is not used in our application.

J4: This is not a jumper, but a test pin to detect a communication failure between the computer and the board.

APPLICATION DIAGRAMS

An application example shown in Figure 7 illustrates connections to the evaluation board and the loads. Cable connections for the PC and the load connection are not supplied with the evaluation board.

The board is fully protected against short circuit to ground and reverse battery conditions. In case of short circuit, some of the power devices can get very hot before they go into thermal shutdown. In case of reverse battery, the power MOSFETs are turned on. In this condition, the loads are likely to conduct current.

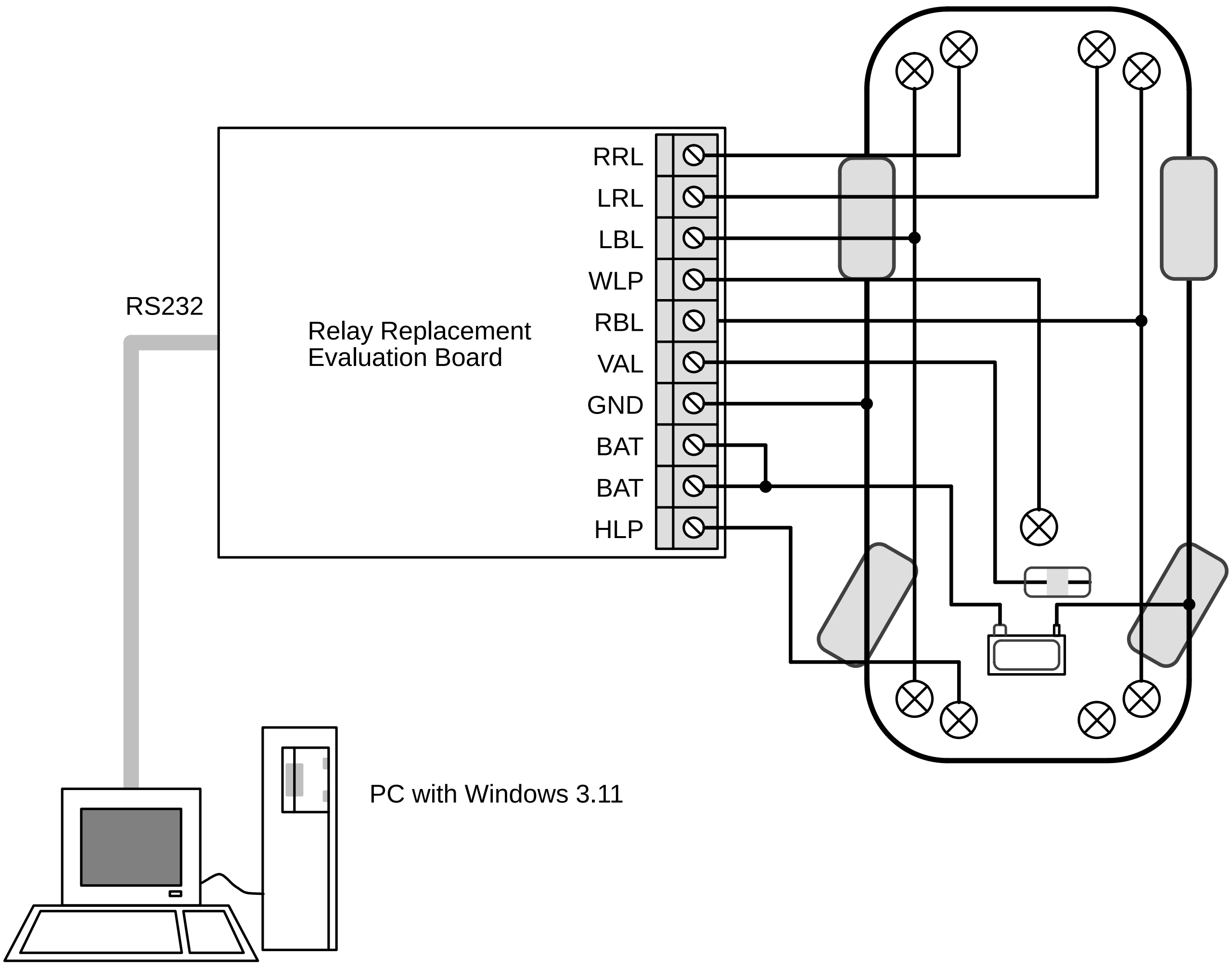

Figure 7. Application Example

Boards contents are described by the following schematic and parts list.

Table 1. Parts List

Item	Quantity	Reference	Part
1	6	R1,R2,R3,R4,R29,R36	470 Ohms
2	19	R5,R6,R7,R8,R9,R10,R12,R13,R16,R17,R20,R21,R22,R23,R24, R25,R26,R27,R34	10 kOhms
3	1	R11	680 Ohms
4	1	R14	270 kOhms
5	1	R15	100 kOhms
6	1	R18	10 MOhms
7	4	R19,R30,R32,R33	1 kOhms
8	1	R28	4,7 kOhms
9	1	R31	2,2 kOhms
10	1	R35	100 Ohms
11	2	C1,C2	22 pF
12	3	C3,C5,C7	10 nF
13	3	C4,C6,C11	0,1 uF
14	2	C8,C9	0,47 uF
15	1	C10	47 nF
16	4	C12,C13,C14,C15	1 uF
17	1	C16	470 uF Chimic
18	2	Z1,Z2	Zener 6,3 V
19	1	POT	10k
20	3	D1,D2,D3	Diode 1N4001
21	1	DiodeRL	Schotcky diode
22	1	P1	DB9
23	1	P2	Screw Terminal
24	4	LED1,LED2,LED3,LED4	Leds
25	1	QUARTZ	8 MHz
26	1	U1	MC68HC811E2
27	2	U2,U3	Opto 4N32
28	1	U4	MC34064P
29	1	U5	Rectifier Bridge
30	1	U6	MC33289
31	1	U7	MC33288
32	2	U8,U9	MC33286
33	1	U10	MC7805CT
34	1	J1	Jumper
35	1	J2	Jumper
36	1	J3	Interrupt pin
37	1	J4	Test pin

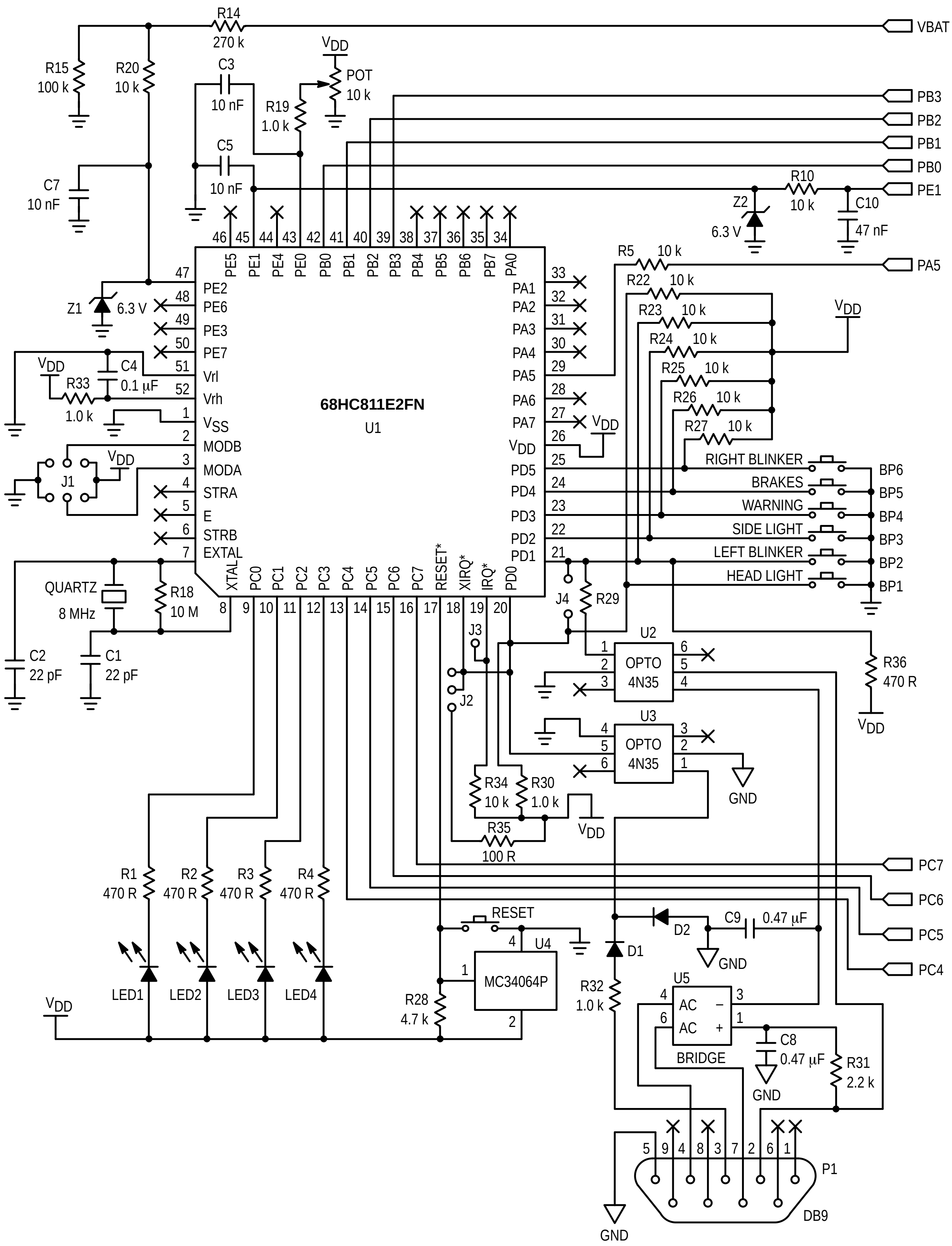
R14
270 k
VBAT
R15
100 k
R20
10 k
C3
10 nF
VDD
POT
10 k
R19
1.0 k
PB3
PB2
PB1
PB0
C5
10 nF
C7
10 nF
R10
10 k
PE1
Z2
6.3 V
C10
47 nF
R5
10 k
PA5
68HC811E2FN
U1
PE5
PE1
PE4
PE0
PB0
PB1
PB2
PB3
PB4
PB5
PB6
PB7
PA0
PE2
PE6
PE3
PE7
Vrl
Vrh
VSS
MODB
MODA
STRA
E
STRB
EXTAL
XTAL
PC0
PC1
PC2
PC3
PC4
PC5
PC6
PC7
RESET*
XIRQ*
IRQ*
PD0
PA1
PA2
PA3
PA4
PA5
PA6
PA7
VDD
PD5
PD4
PD3
PD2
PD1
Z1
6.3 V
C4
0.1 µF
R33
1.0 k
J1
QUARTZ
8 MHz
R18
10 M
C2
22 pF
C1
22 pF
R22
10 k
R23
10 k
R24
10 k
R25
10 k
R26
10 k
R27
10 k
RIGHT BLINKER
BRAKES
WARNING
SIDE LIGHT
LEFT BLINKER
HEAD LIGHT
BP6
BP5
BP4
BP3
BP2
BP1
J4
R29
J3
J2
U2
OPTO
4N35
U3
OPTO
4N35
R36
470 R
GND
R34
10 k
R30
1.0 k
R35
100 R
PC7
PC6
PC5
PC4
R1
470 R
R2
470 R
R3
470 R
R4
470 R
LED1
LED2
LED3
LED4
RESET
U4
MC34064P
R28
4.7 k
D2
C9
0.47 µF
D1
R32
1.0 k
U5
AC
AC
BRIDGE
C8
0.47 µF
R31
2.2 k
P1
DB9

Figure 8.

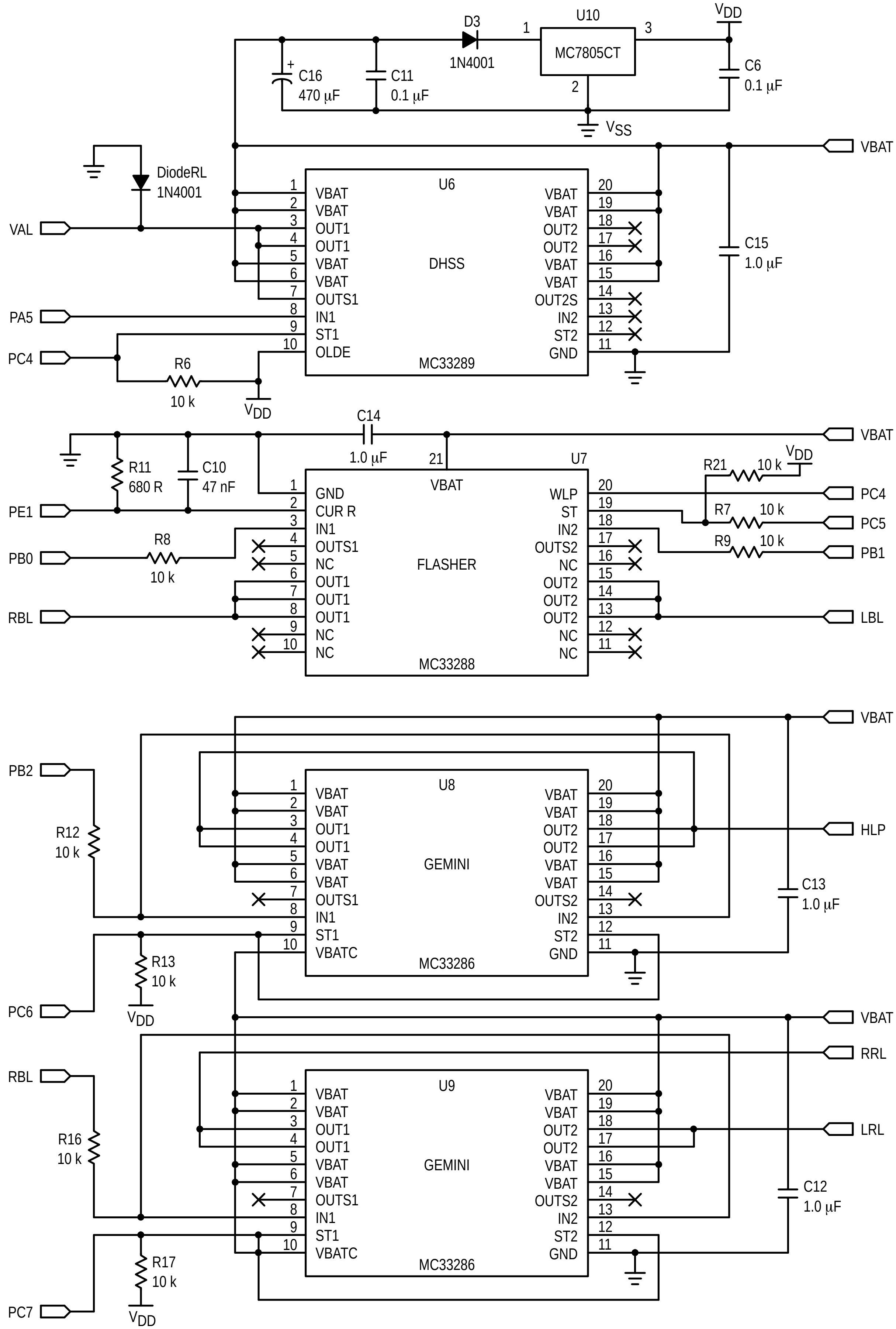
D3
1N4001
U10
MC7805CT
1
3
2
VDD
VSS
C16
470 µF
C11
0.1 µF
C6
0.1 µF
VBAT
DiodeRL
1N4001
VAL
U6
DHSS
MC33289
VBAT
VBAT
OUT1
OUT1
VBAT
VBAT
OUTS1
IN1
ST1
OLDE
VBAT
VBAT
OUT2
OUT2
VBAT
VBAT
OUT2S
IN2
ST2
GND
C15
1.0 µF
PA5
PC4
R6
10 k
VDD
C14
1.0 µF
VBAT
R11
680 R
C10
47 nF
PE1
PB0
R8
10 k
RBL
U7
FLASHER
MC33288
GND
CUR R
IN1
OUTS1
NC
OUT1
OUT1
OUT1
NC
NC
VBAT
WLP
ST
IN2
OUTS2
NC
OUT2
OUT2
OUT2
NC
NC
R21
10 k
R7
10 k
R9
10 k
PC4
PC5
PB1
LBL
VBAT
PB2
R12
10 k
U8
GEMINI
MC33286
VBAT
VBAT
OUT1
OUT1
VBAT
VBAT
OUTS1
IN1
ST1
VBATC
VBAT
VBAT
OUT2
OUT2
VBAT
VBAT
OUTS2
IN2
ST2
GND
HLP
C13
1.0 µF
R13
10 k
PC6
VBAT
RRL
RBL
R16
10 k
U9
GEMINI
MC33286
LRL
C12
1.0 µF
R17
10 k
PC7

Figure 9.

Blinker Failed Lamp Detection

It is important that the driver be warned whenever a bulb has failed. The difficulty of this function for the blinker application lies in the fact that the Flasher drives several bulbs simultaneously. The Flasher device features a current recopy function that allows the microcontroller to monitor load currents while the outputs are on.

If the output current changes beyond a certain limit, the microcontroller warns the driver that one of the blinker lamps is damaged by causing the working lamps to blink at double frequency.

But in reality, it is not that simple. Tolerance in the measurement chain has to be taken into account as well as the load tolerances. Additionally, the load current varies with changes in the battery voltage. Therefore, accurate monitoring of the battery voltage is required by the microcontroller. Another error factor is the 5W vehicle side bulbs that can be on or off without altering the diagnostic result.

The tolerance of the measurement chain is mainly due to the Flasher current recopy accuracy which is specified at ±10% over the temperature range from –40°C to +125°C. The 21W bulbs are specified at ±6% accuracy and the 5W bulbs at ±10%.

With the given tolerance, a single 21W bulb failure out of two can be detected as described in Figure 10.

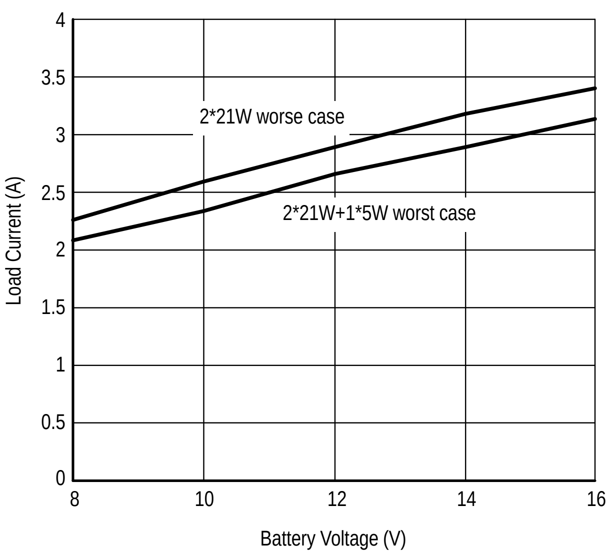

Figure 10. Failed Lamp detection out of 2 lamps

If a trailer is connected to the vehicle, the detection with absolute limits is no longer possible because the lower and the upper limits overlap.

In the program developed for the evaluation board, we decided to implement a different approach based on a relative comparison. The idea is to be able to store the value of the load current in a non–volatile memory. Each time the system is turned on, the measured current is compared to the stored value. If the difference between the two values is below a certain percentage, the stored value will be refreshed. On the other hand, if the difference is above a certain limit, a failed bulb will be reported.

Detecting a failed lamp on the trailer is also possible. The software compares the left and right channel currents. If it detects 3 bulbs on one side and 2 on the other, it will detect a failed bulb.

The advantage of this relative approach is that the system adapts as it is modified over time, and with the part to part variation for each component of the measurement chain.

The only limitation of this solution is that if the trailer is removed while the car is powered up (no RESET), the first time the blinker is on, the microcontroller will detect a failed bulb.

This solution requires the storage of 2 values in a non volatile memory and a calibration the very first time the car is powered up. The micro used in our demonstration board is not capable of such a feature, and the calibration is done at every RESET. This is the reason why the blinker bulbs are turned on after every RESET.

In the algorithm implemented in the evaluation board, any current recopy variation above 22% is considered a failure.

CONCLUSION

The Relay Replacement Evaluation Board is a tool allowing rapid evaluation of several different solid state relays developed by Motorola. Their thermal and electrical behavior can rapidly be analyzed before going further with PCB development. In addition, the board design can be used as a reference for speeding hardware development.

NOTES

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