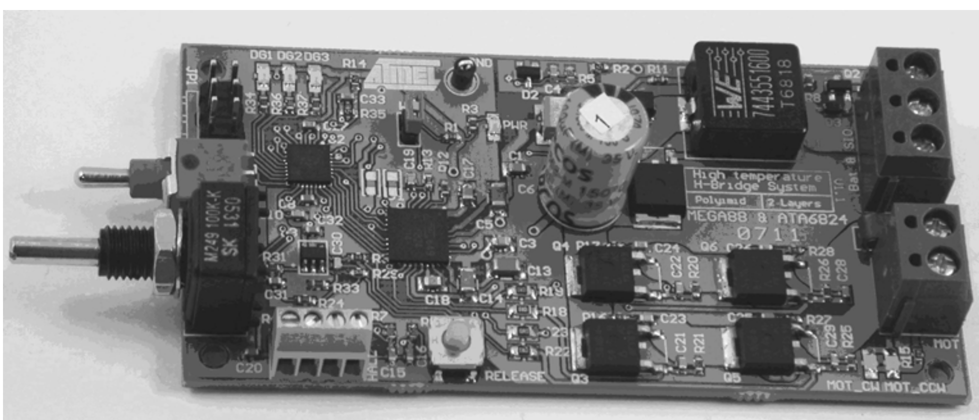
Atmel ATA6824 and Atmel ATmega88: DC Motor Control in High Temperature Environment

1. Introduction

The purpose of this document is to explain Atmel®'s High Temperature H-bridge Motor Control System. The demand for driver solutions in "under-the-hood" environments is rapidly increasing, and in particular, the use of applications such as turbo chargers, EGR, or AGR calls for new solutions.

Figure 1-1. Atmel ATA6824 and Atmel ATmega88



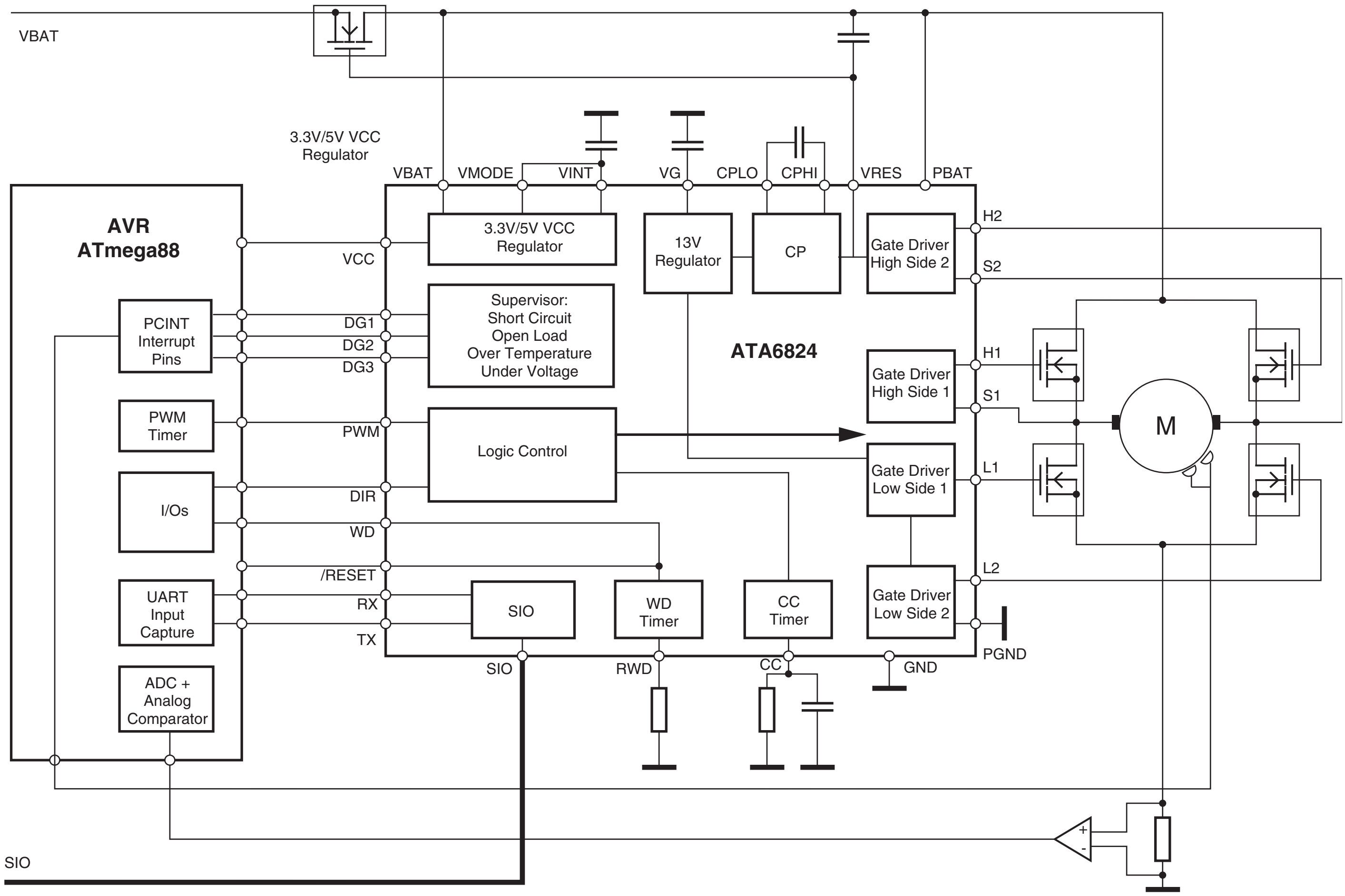
Atmel ATA6824 and Atmel ATmega88

Application Note

9102B–AUTO–03/11

2. H-bridge Motor Control System

Figure 2-1. Fully Integrated H-bridge Motor Control Application



The system consists of two integrated circuits: the Atmel® microcontroller ATmega88 and the Atmel H-bridge DC Motor Driver ATA6824.

The Atmel ATA6824 features gate drivers to drive H-bridge FETs, voltage regulator, watchdog, and serial IO interface. An integrated charge pump controls the NMOS FETs for low-side and high-side switches. In addition, the charge pump voltage is capable of providing a low-drop inverse voltage protection. Therefore, only a NMOS FET in the source drain direction is necessary.

The Atmel ATA6824 switches the outputs off in the event of short circuits, voltage failures, and overtemperature. Temperature prewarning and charge pump failures are also indicated. The application circuit includes a current shunt, which can react at different current levels. The current signal is prepared for the microcontroller by an amplifier.

The Atmel ATmega88 generates the PWM speed signal to run various movement profiles as required for the load.

2.1 Cooling Area Design

The Atmel® driver IC ATA6824 is housed in a QFN package. QFN packages are particularly suitable for power applications because of the exposed die pad. To make use of this advantage, the heat slug must be completely soldered to the PCB.

To reduce thermal resistance, vias etched down to the soldering layer are required. An adequate ground plane must be placed on the soldering layer to eliminate the thermal energy.

A via diameter of 0.3mm to 0.4mm with a spacing of 1mm to 1.5mm has proven to be most suitable. Care should be taken of the copper area's planarity to avoid, in particular, any solder bumps arising at the thermal vias.

3. High Ambient Temperature

The application is designed for high temperature environments. The Atmel ATmega88 and the Atmel driver ATA6824 are qualified up to an ambient temperature of 150°C. Under thermal overload conditions, the Atmel ATA6824 switches off. If the temperature exceeds the prewarning threshold, the microcontroller can reduce the output power.

Capacitance material on X8R quality is necessary to ensure high ambient temperatures.

Mounted connectors, a switch, and a potentiometer on the board, enable prototyping; however, these components are not qualified for use under high temperatures. The board can be integrated into high-temperature environments using wires.

4. The Application Board

The application board is run-capable when connected to nominal 12V at the battery connector (see Figure 4-1 on page 4). The board can be connected to the automotive environment over an SIO bus.

A mounted switch (DIR) for run/stop, clockwise, and counterclockwise movement and a potentiometer (SPEED) for variable speed (PWM) input are available on the application board to enable stand-alone prototyping.

An optional feedback loop from the DC motor to the Atmel ATmega88 can be established using Hall sensor(s). The two Hall inputs can be linked to the connector HALL as well as the 5V supply for the Hall sensors. There is also an on-board shunt current sensor to detect over-currents (using Atmel ATmega88's analog comparator) and to measure motor current.

4.1 On Board Features

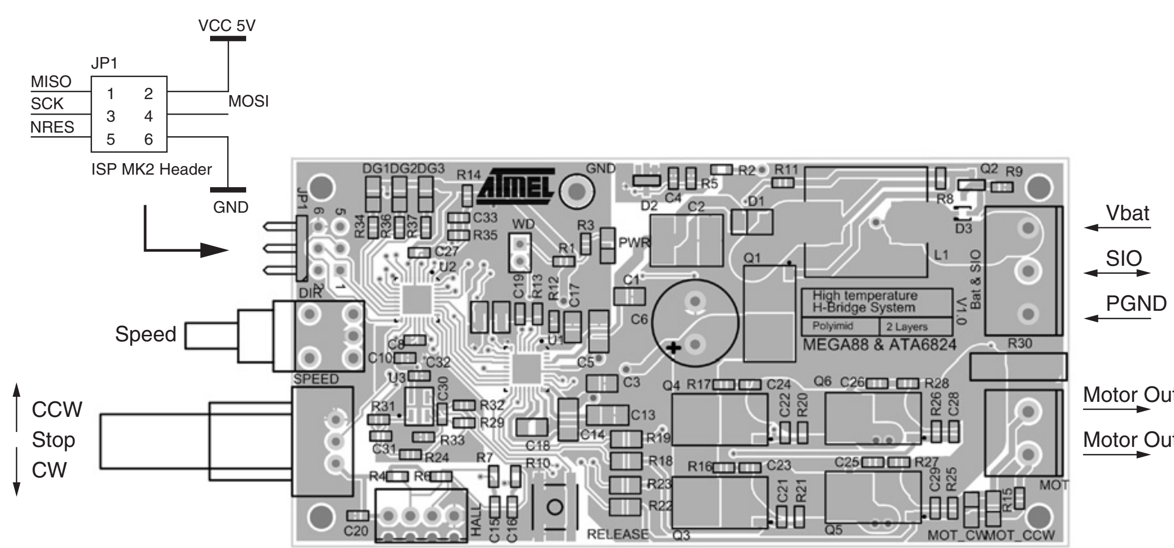
The application board provides the following features:

- Atmel ATmega88 QFN32
  - MCU
- Atmel ATA6824 QFN
  - 5V/3.3V voltage regulator (fixed on-board to 5V)
  - Low drop voltage protection management
  - H-bridge driver with diagnostics
  - Serial link transceiver to connect board to external environment
  - Watchdog

- On-Off-On switch
  - Stand-alone commands interface: Run/stop, clockwise, and counterclockwise
- Potentiometer
  - Standalone speed variation command (PWM ratio)
- System clock
  - MCU internal RC oscillator
- Power H-bridge (4 power FET)
- Human interface
  - Diagnostics signaling/latching through LED and unlatching through push button
- Connectors
  - Power supply (battery voltage) and SIO
  - DC motor connector
  - Hall sensor inputs and supply (2 filtered inputs and 5V regulated supply voltage)
  - SP/debugWire connector, for on-chip in-situ programming (ISP) and for on-chip debugging using JTAG ICE supported by AVR Studio® interface(1)
- Dimensions: 45mm × 90mm

Note: 1. The Atmel ATmega88 is supported by AVR Studio, version 4.12 or higher. For up-to-date information on this and other AVR® tool products, please consult our web site. The newest version of AVR Studio, AVR tools, and user guide can be found in the AVR section of the Atmel web site, http://www.atmel.com

Figure 4-1. Application Board Top View, and Connector Usage



5. Software Description

All code is implemented in C language. Source code can be compiled using IAR® EWAVR 4.20A as well as AVR-GCC (WinAVR-20060421 with AVR Studio).

HTML documentation is included in the package. Use the High_temp_brushed_DC.html file in the root directory to start viewing the documentation.

5.1 Motor Management

- Motor stopped
  – PWM ratio is set to zero
  – Command switch inputs are monitored to start motor or keep it stopped.
- Motor running
  – Atmel® ATA6824 DIR pin is set according to command direction. PWM ratio is refreshed constantly according to speed of the potentiometer ADC input.
  – Command switch inputs are monitored to stop motor or keep it stopped.
- Degraded "mode":
  – Atmel ATA6824 detects a short circuit: H-bridge short-circuited and FET is switched off until next PWM rising edge. This default is reported to software through a diagnostic feature: an interrupt occurs on DG1 MCU input pin, which internally latches a failure. Apart from switching on the DG1 LED, no action is taken by the software in response to this event. In a customer application, this should be managed, eventually by the interrupt sub-routine, especially in case of a 100% PWM ratio where no rising edge appears at the Atmel ATA6824 PWM input to make a retry. Care should be taken in motor transient state (e.g. motor start-up). An accelerating curve is preferable from 0% to 100% PWM ratio transition, which may be mistaken for a short-circuit condition. Without management, in the worst case scenario, the motor will not start as the outputs are switched off, and short circuit will be shown on DG1 pin.
  – Atmel ATA6824 detects an over-temperature warning: an interrupt occurs on the MCU. This diagnostic doesn't need to be software latched as it remains high until the temperature decreases. The application software toggles an LED.
  – Atmel ATA6824 detects an under-voltage, an over-voltage, or a charge pump failure. Then, an interrupt occurs on DG2 MCU input PIN. This diagnostic is latched by software and an LED is switched on.
  – An overcurrent is detected by the analog comparator. An interrupt is generated. The output PWM is then disabled until the current decreases bellow the over-current limit.

5.2 Resources

Table 5-1. Code, Data, and CPU Resources (without Compiler Optimizations)

Compiler/Resources	Code Size (Flash)	Data Size (Ram)	CPU Load
IAR EWAVR 4.20A	1 180 bytes	335 bytes	All routines are constantly executed in main loop
AVR-GCC	1724 bytes	15 bytes	

The following MCU peripherals are used:

- Timer 0
  - PWM generation through output compare 0B (OC0B pin)
- ADC channels 0, 6, and 7
  - Resp. current, battery supply voltage and desired speed (potentiometer) value acquisitions.
- Pin change interrupts
  - DG1, DG2 and DG3 diagnostic pins interrupts
  - Optional hall sensors
- Analog comparator
  - Generates over-current interrupts
- I/O
  - LEDs, switch and push-button operations, watchdog trigger, motor direction command
- Additional (not managed by this stand-alone software)
  - UART for SIO implementation (communication through high-voltage serial interface).

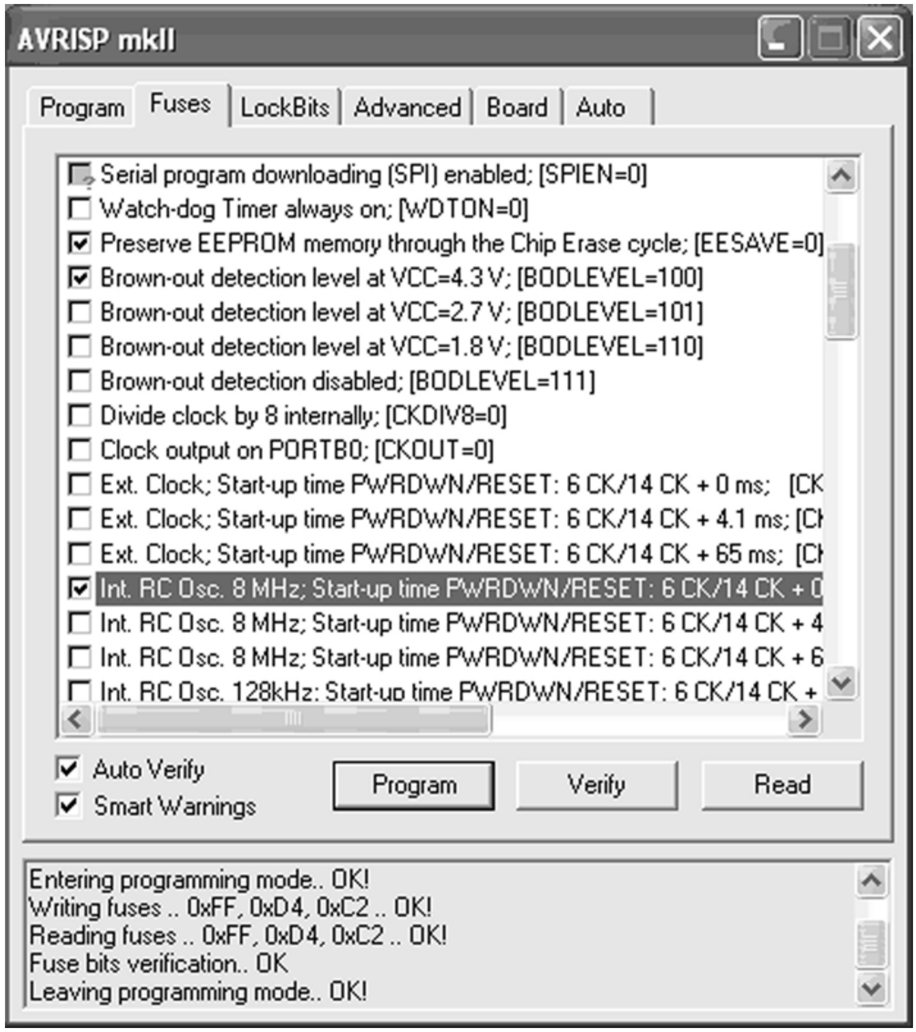
5.3 Caution about Atmel ATmega88 Start-up Time (Fuse Configuration)

ATA6824 uses a windowed watchdog, which can reset the Atmel® ATmega88 using the reset pin.

- Atmel ATmega88 is configured by default (fuse configuration) with a start-up time of 65ms after a power-on reset. With tolerances, this value can increase up to 69ms.
- Atmel ATA6824 waits for a watchdog trigger within 68ms after the reset signal has been released.

Such an additional 65ms delay is unnecessary and could cause the application not to start. Atmel ATA6824 ensures an adequate VCC through its power-on delay. Atmel ATmega88 default fuse configuration should be over-written with a smaller start-up time. The start-up time can be set to 4.1ms or 0ms. The start-up settings in the fuse configuration can be changed by setting the SUTx and CKSELx fuse bits. Further details about fuses can be found in the Atmel ATmega88 datasheet and in the AVR Studio Help: AVR Tools user's guide.

Figure 5-1. Atmel® ATmega88 Fuse Configuration Editing in AVR Studio



5.4 Diagrams

Figure 5-2. Flowchart for Analog Comparator (Over-current) ISR

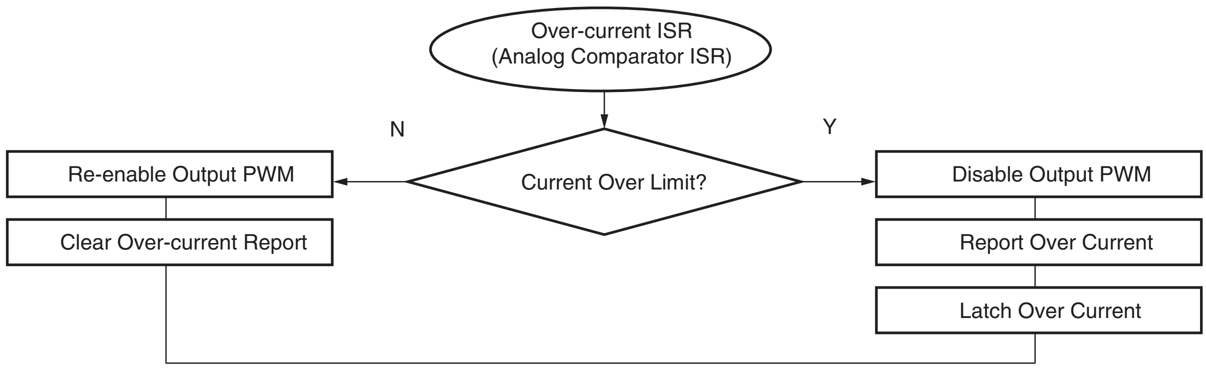


Figure 5-3. Flowchart for Optional Hall Sensors ISR

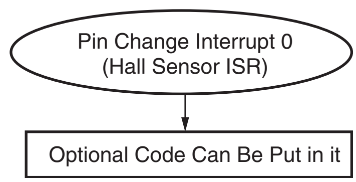


Figure 5-4. Flowchart for Diagnostic Interrupt Pins

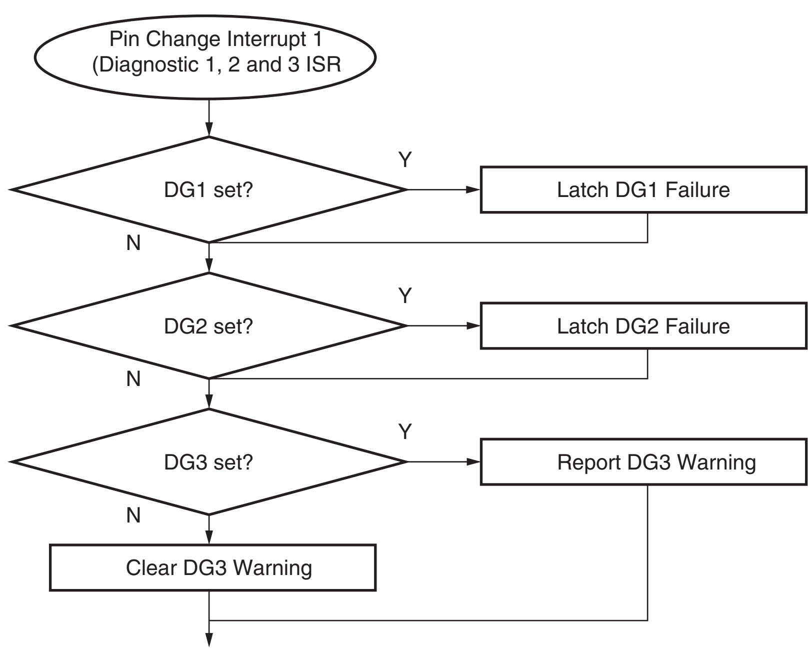
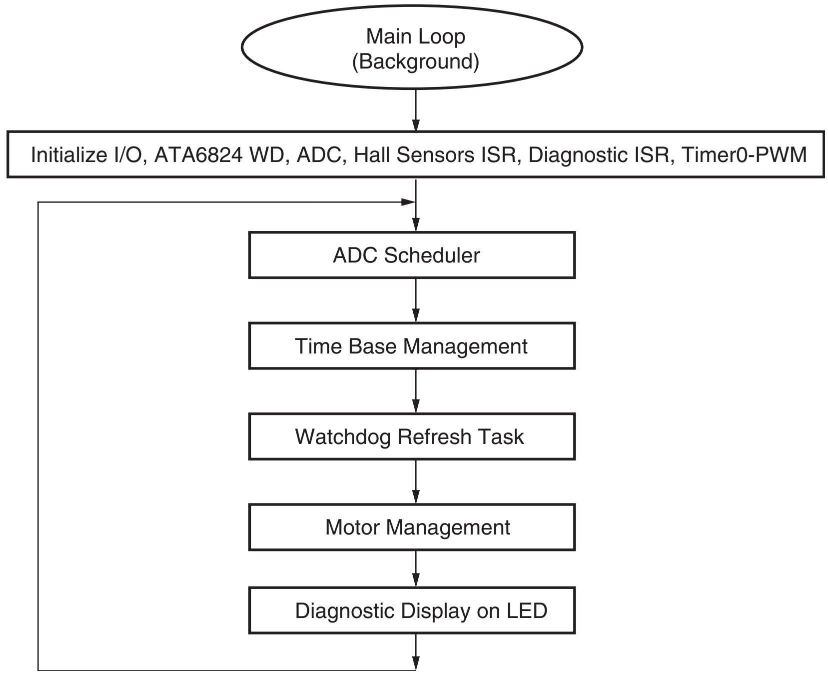


Figure 5-5. Main Loop Flowchart



5.5 Modules

```
void ADC_Init(); (void)
```

Sets up ADC to acquire desired speed from potentiometer.

```
void Timer0_start(void)
```

Configures timer 1 for PWM on Output compare 0 B pin.

```
void AN_compare_init(void)
```

Configures Analog comparator to detect over-currents by interrupts.

```
void Hall_sensors_ISR_init(void)
```

Sets up pin change interrupts on hall sensors inputs.

```
void Diag_inputs_ISR_init(void)
```

Sets up interrupts on Diagnostic pins.

```
void ADC_task(void)
```

Schedules ADC acquisitions: desired speed, Vbat, and Motor current. It is called in background (main loop).

```
unsigned int adc_get_speed(void)
```

Returns last acquired desired speed from potentiometer.

```
unsigned int adc_get_current(void)
```

Returns last acquired motor current.

```
unsigned int adc_get_V_bat(void)
```

Returns last acquired supply voltage measurement.

```
void manage_time_base(void)
```

Manages a general purpose time base by monitoring Timer0 overflows (used by watchdog refresh routine, LED toggling…).

```
void refresh_ATA6824_watchdog(void)
```

Refreshes ATA6824 according to hardware fixed period and software time base. It is called in background (main loop).

```
void clear_faults(void)
```

Clears software latched faults (from diagnostics pins) only when they have disappeared.

```
TIMER0_SET_OC0B_PWM (val)
```

This macro changes PWM ratio.

```
DISABLE_OCB0()
```

This macro disables PWM output by changing pin multiplexing back to general I/O configuration.

```
RE_ENABLE_OCB0()
```

This macro enables PWM output by giving pin control to Output compare 0 B (Timer 0 PWM output).

6. Application Board Full Description

Figure 6-1. BLDC Application Board Schematic

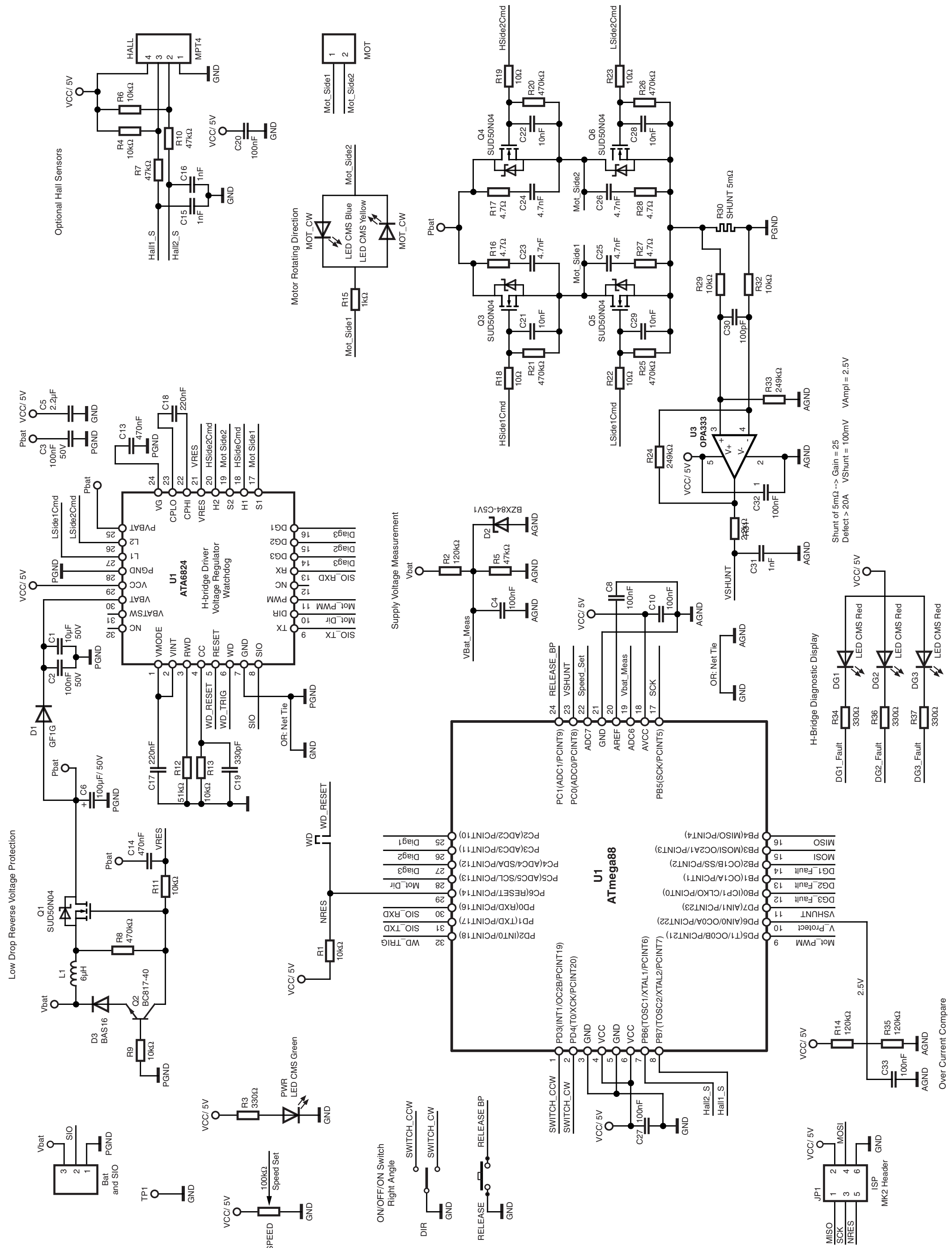


Figure 6-2. BLDC Application Board Top View and Component Placement

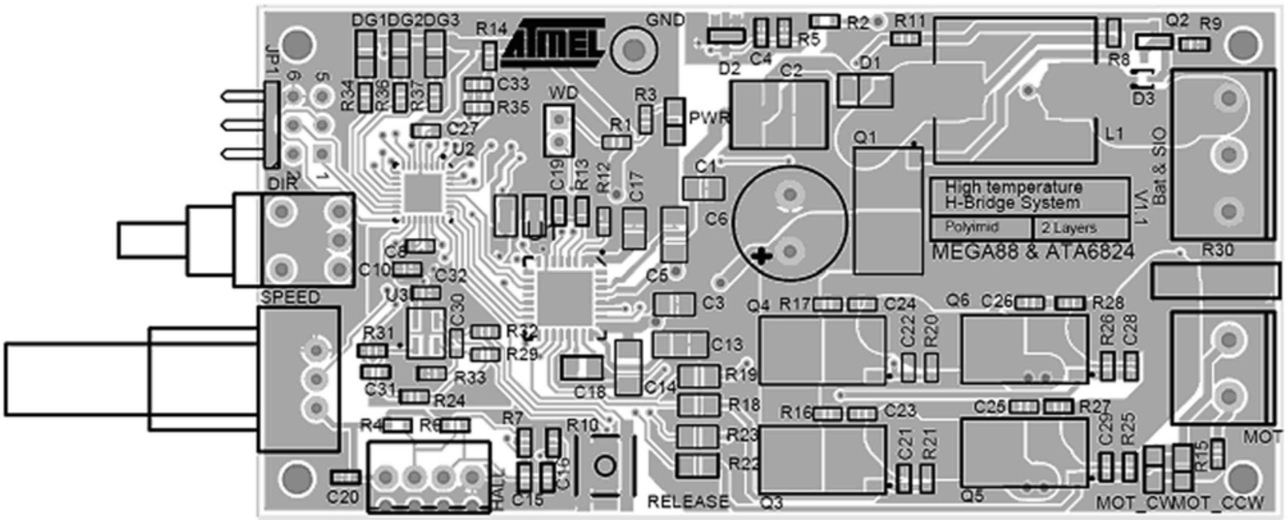
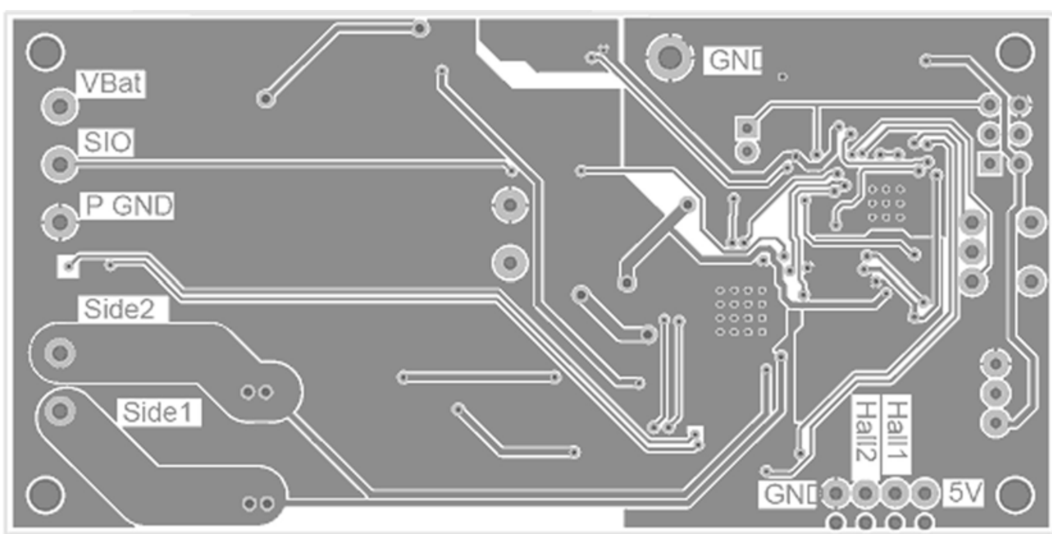


Figure 6-3. BLDC Application Board Bottom View



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