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Application Note

Digital Direct Current Ignition System Using HC08 Microcontrollers

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This application note describes a reference design for an engine electronic ignition system, known as digital *Direct Current Ignition (DCI)*. The DCI system is targeted for single-cylinder, two-stroke engines such as mopeds. At the heart of the system is a Freescale HC08 microcontroller, the MC68HC908JK3.

The text contains a brief overview of the DCI method, and a description of the demo circuit constructed in the laboratory, using the MC68HC908JK3 as the controller.

For full MC68HC908JK3 specification, please refer to the data sheet, Freescale order number: MC68HC908JL3/H.

Introduction

In the past, the two-wheelers industry: scooters, motorcycles, and mopeds, commonly used an engine ignition system based on the capacitive discharge method, known as *capacitive discharge ignition (CDI)* (described in Freescale application note AN4006/D). The CDI system saves having the battery to generate the ignition spark and thus prolonging battery life. More recently, manufacturers are turning to an alternative method for electronic ignition, known as *Direct Current Ignition (DCI)*.

The DCI method is sometimes called *Inductance Direct Ignition (LDI)*, because this ignition system uses the battery to supply a DC current to charge an inductor, and then released as a high voltage pulse via a step-up transformer to the spark plug to ignite the fuel mixture in the combustion chamber. Compared with the CDI system, the DCI system reduces the charging

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complexity in the magneto circuit, and thus eliminating the AC high voltages across the capacitor during charging periods. The DCI method also prolongs the system lifetime, since the average lifetime of high voltage capacitors in CDI systems is about one to two years.

At the heart of this DCI system demo is the MC68HC908JK3 MCU. An 8-bit MCU with 4 k-bytes of user FLASH memory, I/O ports, analog-to-digital converter, and a flexible 16-bit timer with input capture and output compare functions. Other components used in this demo is similar to that of the CDI system, but without the high-voltage capacitor. The following sections described the DCI demo in detail.

Digital DCI Module

Figure 1 is a block diagram showing the digital DCI module. At the heart of the timing control circuit is the MC68HC908JK3 MCU; monitoring the engine speed and throttle setting, whilst calculating the ignition timing. The demo module produces the spark necessary to ignite the air/petrol mixture in the combustion chamber with variable timing against the speed of the engine.

The digital DCI module is divided into the following control blocks:

- Regulated power supply
- Analog ignition control
- Throttle input

- Signal shaping
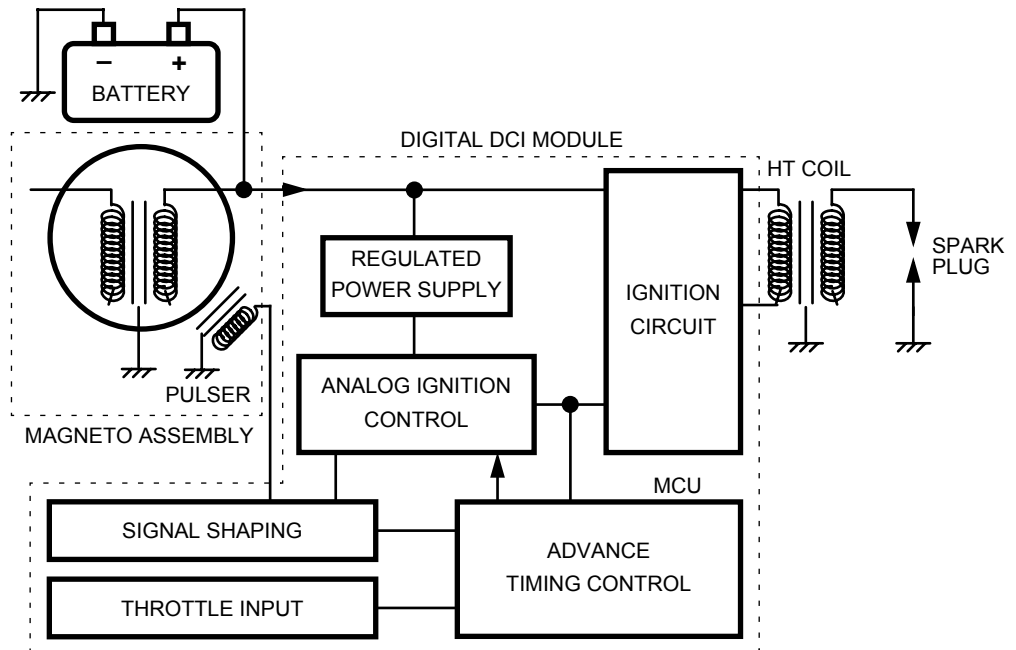- Advance timing control
- Ignition circuit

Figure 1. Digital DCI System Block Diagram

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Power Supply

The 12V from the battery is stepped down to 5V using a MC7805 voltage regulator, and provides the power source to the controlling circuits. The capacitors C4 and C6 help to maintain a steady voltage in case of sudden voltage transients.
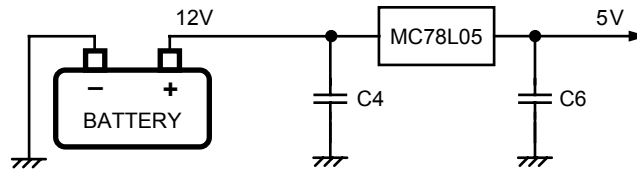

Figure 2. DC Power Supply

Signal Shaping

The *signal shaping* circuit is designed for converting the AC pulses from the pulser to DC pulses. The circuit uses low input voltage comparators with hysteresis characteristics.
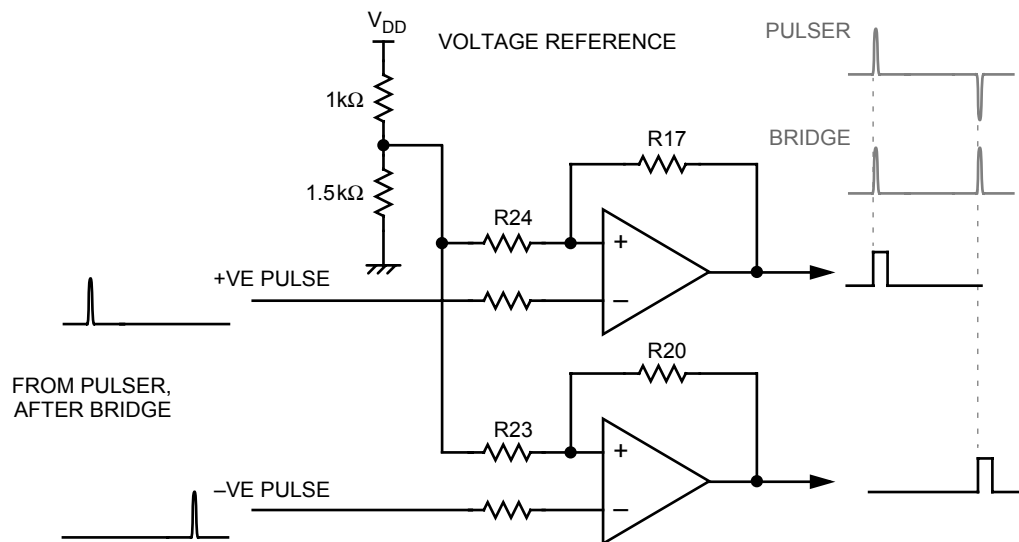

Figure 3. Signal Shaping

Analog Ignition Control

This *analog ignition control* circuit is designed for engine start-up, since the MCU has to wait for at least two engine revolutions to get the initial engine speed. From Figure 4, the first pulse switches on the IGBT (Insulated Gate Bipolar Transistor) to charge the HT primary coil and the second pulse switches off the IGBT to produce the high voltage ignition pulse. The ignition timing follows the signal of the pulser (Figure 3). Diodes D3 and D4 isolate the control between the MCU and the analog ignition circuit.

Once the MCU is ready, it will isolate the analog ignition circuit by switching on Q4. The ignition circuit will then be directly controlled by the MCU.
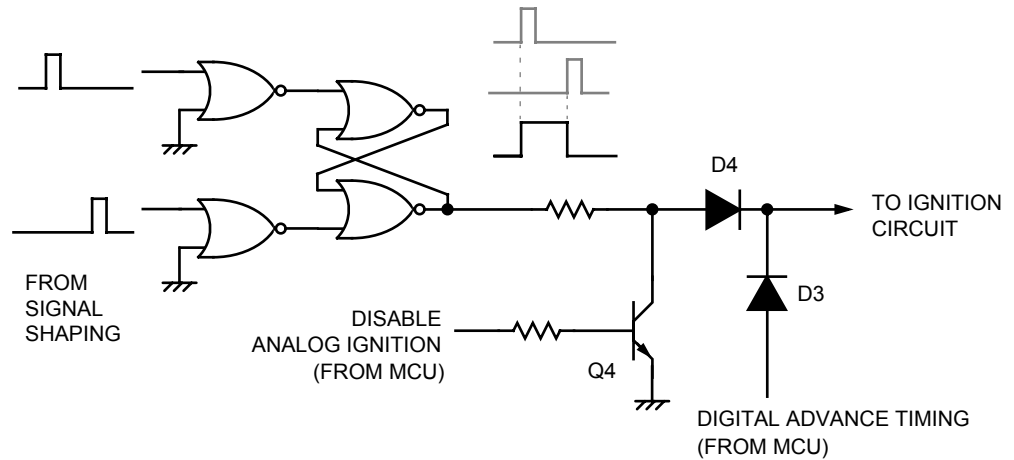
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Figure 4. Analog Ignition Control

Advance Timing Control

At the heart of the *advance timing control* circuit is the MC68HC908JK3 MCU. The main function of the MCU is to monitor the speed of the engine and throttle setting, and calculating the optimum ignition time. The engine speed is determined by using the MC68HC908JK3's 16-bit timer to calculate the time interval for the recurring pulses (from the signal shaping circuit) to the $\overline{IRQ}$ pin. Together with the throttle setting input, the optimum time for the ignition pulse is calculated. Before the ignition spark can be fired, time is required for the HT primary coil to charge up and collapsed at the ignition instance. Therefore, before the ignition instance, the MCU has to switch on the IGBT to charge up the primary coil. At the ignition instance, the MCU switches off the IGBT. This causes the current flowing in the primary coil to collapse, and inducing a high voltage on the secondary coil to the spark plug.

It should be noted that the HT primary coil should not be charged for excessive periods. Long period of continuous charging causes the primary coil to overheat. Therefore, the coil should only be charged just before the ignition pulse is required. This charging period is controlled by the MCU.

In the demo, the engine speed is indicated using an external tachometer. This tachometer is driven by the TCH1 pin, configured as a PWM output, from the MC68HC908JK3's timer. The PWM pulse width is proportional to the pulses from the pulser.

Throttle Control

The throttle input can be simulated using two methods. An analog throttle can be simulated using an ADC input of the MC68HC908JK3 to monitor the variable voltage from a potentiometer, as in Figure 5a. With the 8-bit ADC, the input level can be divided into 256 steps. The alternative method is to use a standard MC68HC908JK3 I/O port to monitor throttle ON and throttle OFF, as in Figure 5b.
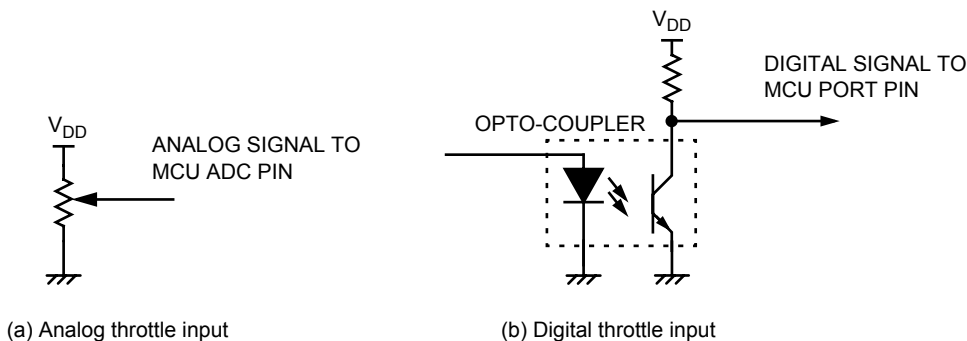
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(a) Analog throttle input   (b) Digital throttle input

Figure 5. Throttle Input

Ignition Circuit From Figure 6, prior to the ignition instance, the IGBT is switched on to charge the HT primary coil. At the ignition instance, the IGBT is switched off. The sudden collapse of current flow in the primary coil produces a high voltage pulse across the coil. This high voltage pulse is then induced to the step-up secondary coil to produce a several kV pulse for the spark plug. Typically, the HT primary coil (at 4Ω, 10mH) requires a voltage between 300 to 400V to induce the high-voltage on the secondary coil to produce a spark for an 8mm distance. Therefore, the IGBT must be rated for handling this voltage.
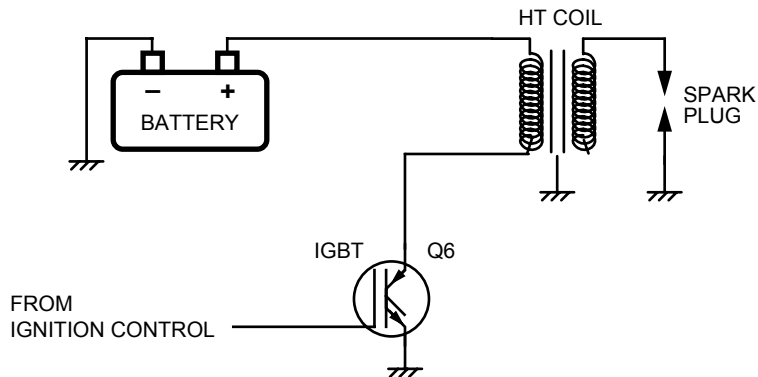
Figure 6. Ignition Circuit

Digital DCI Operation

The typical operation of the digital DCI module can be divided into three modes:

1. Engine start-up: The ignition timing is provided by the pulses from the pulser.
2. Intermediate engine speeds: Depending on throttle setting, the ignition advance follows typically the curves shown in Figure 7.
3. High engine speeds: The ignition speed is applied with a fixed firing angle. This also depends on the throttle setting.

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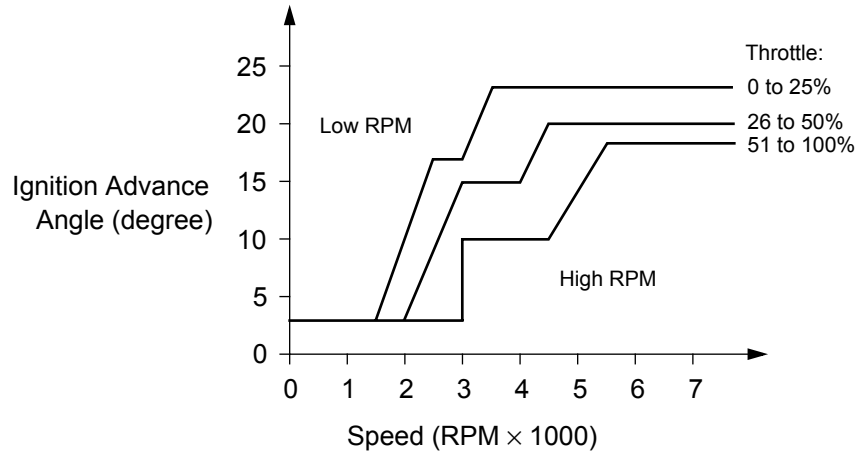
Figure 7. Example of Ignition Advance Characteristics

The period of pulses (positive and negative) generated from pulser (mounted on the magneto) is proportional to the engine speed. The pulses then passes through the signal shaping circuit to be converted to the MCU input level. The MCU then captures these pulses to calculate the output ignition angle. The HT primary coil is charged prior to the ignition pulse. The ignition timing diagram is shown in Figure 8.
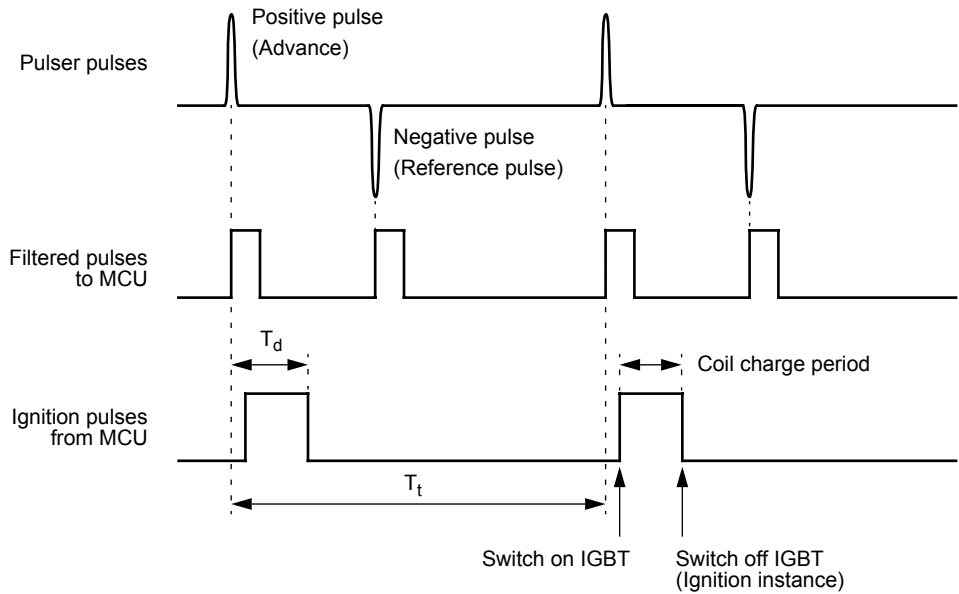
T_d = Delay value calculated with respect to positive pulse (Advance)

T_t = Time period (in seconds)

$$\text{Engine RPM} = \frac{1}{T_t} \times 60$$

Figure 8. Ignition Advance Waveforms

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Figure 9. DCI Module Schematics

Extra Features

This project demonstrated the basic DCI system. Other features, such as over-current/temperature protection and sensor inputs can be added to the system to fully utilize the MC68HC908JK3 MCU. One of the desired features is a fail safe or fall back mechanism for MCU failure. If a MCU failure occurs, the system should fall back to the analog ignition mode, as the pulses from the pulser are always present. The *computer operating properly (COP)* module inside the MC68HC908JK3 can be used for this purpose.

Further Information

Reference Design   The digital DCI reference design using MC68HC908JK3, with PCB layout and MCU source code are available from Freescale. Please contact your local Freescale representative for further details.

Related Documents   AN4006/D: Digital Capacitive Discharge Ignition System using HC05/HC08 8-Bit Microcontrollers

AN2158/D: Designing with the MC68HC908JL/JK Microcontroller Family

AN-HK-33/H: In-circuit programming of FLASH memory in the MC68HC908JL3

MC68HC908JL3/H: MC68H(R)C908JL3/JK3/JK1 Technical Data

MC68HC08JL3/H: MC68H(R)C08JL3/JK3/JK1 Technical Data

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