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REFERENCE DESIGN 5223 INCLUDES: √Tested Circuit √Schematic √BOM √Description √Layout

Designing a Temperature-Based Heating System for an Automotive Engine Preheater

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Abstract: This reference design describes how to design hardware for a temperature-based heating system for a vehicle that has an engine preheater installed, based on ambient temperature and a preordained engine start time. This system can also be used for other purposes, such as turning on a storage heater if the ambient temperature falls below a preordained value.

Overview

Winter can be very cold in Nordic countries; it is fairly normal to have temperatures below -20°C. Not everyone has a warm garage for their vehicles, so many people use an engine preheater, like the one shown in **Figure 1**.

Figure 1. An engine preheater. Image courtesy of DEFA.

The engine preheater is mounted into the vehicle (**Figure 2**) and typically heats the water inside the engine.
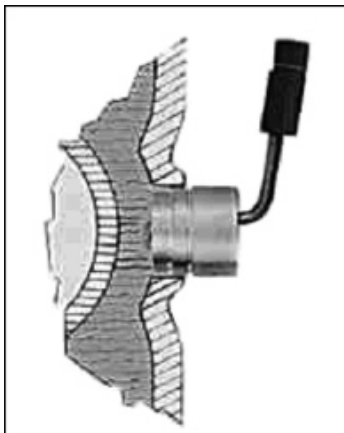
Figure 2. An engine preheater installed in a vehicle. Image courtesy of DEFA.

Starting a vehicle in a cold environment will put an engine under heavy stress. Starting an engine at -30°C puts the same wear on the engine as driving 600km (373 miles). Gasoline consumption during a cold start is much higher than the start of a preheated engine. Preheating the engine results in energy and cost savings, and creates less pollution.

There are two types of preheaters: one uses gasoline as energy and the other uses electricity. This article describes how to design a temperature-based heating system for an electrical engine preheater. Regardless of whether one uses an engine block heater, hose heater, oil heater, or contact heater—this temperature-based heating system described in this article will function correctly.

Recommended Preheating Time

Figure 3 shows preheating time as a function of ambient temperature. Preheating the engine is particularly relevant when the temperature is 5°C or lower. More than three hours of heating time is not recommended, as by that time, the engine is usually preheated up to its maximum temperature. If a user continues heating after three hours, valuable energy is wasted.
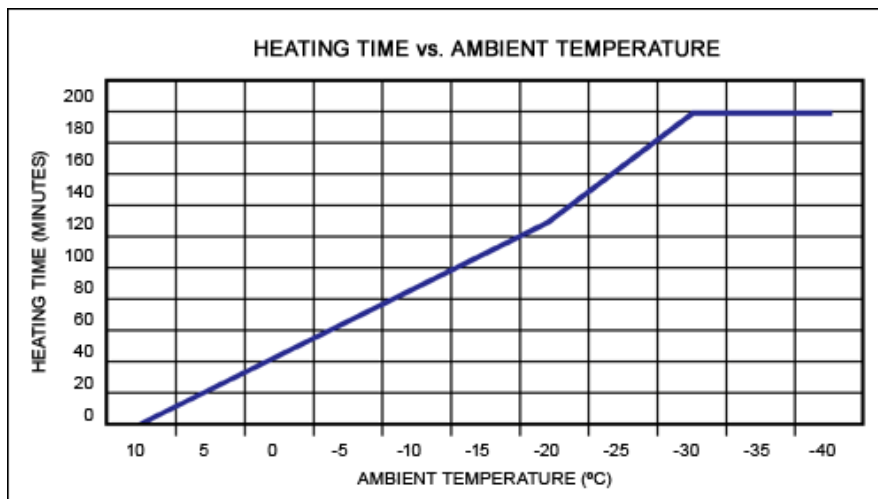

Figure 3. Engine preheating time versus ambient temperature.

Engine preheaters can be turned on manually or automatically with a timer. A user must manually turn on the system well in advance of the preheated start, because if the ambient temperature is very low, the recommended preheating time can be up to 180 minutes. This is not practical if the user needs to leave early in the morning. Alternatively, a user can program a timer to connect electricity to an engine preheater at a preordained time. This would require constantly checking the weather forecast to decide the optimum preordained time. Some car owners just set their timer for 120-minute preheating time, regardless of the ambient temperature. But this practice results in wasted energy.

This application note discusses how to design a convenient and efficient system that knows the desired engine starting time and ambient temperature. This system then uses that information to start the engine preheater at precisely the correct time to heat the car before starting, resulting in maximum energy and cost savings.

Temperature-Based Heating-System Description

A temperature-based heating system needs to measure the ambient temperature. The system should also know both the current time and desired engine starting time. The user interface is, of course, a must to tell the system the desired starting time, which may not always be consistent. The system should also connect and disconnect electricity to and from engine preheater. Because of possible power cuts, time information would need to be backed up with a battery. When all is put together, these components result in a system block diagram, like the one shown in **Figure 4**.
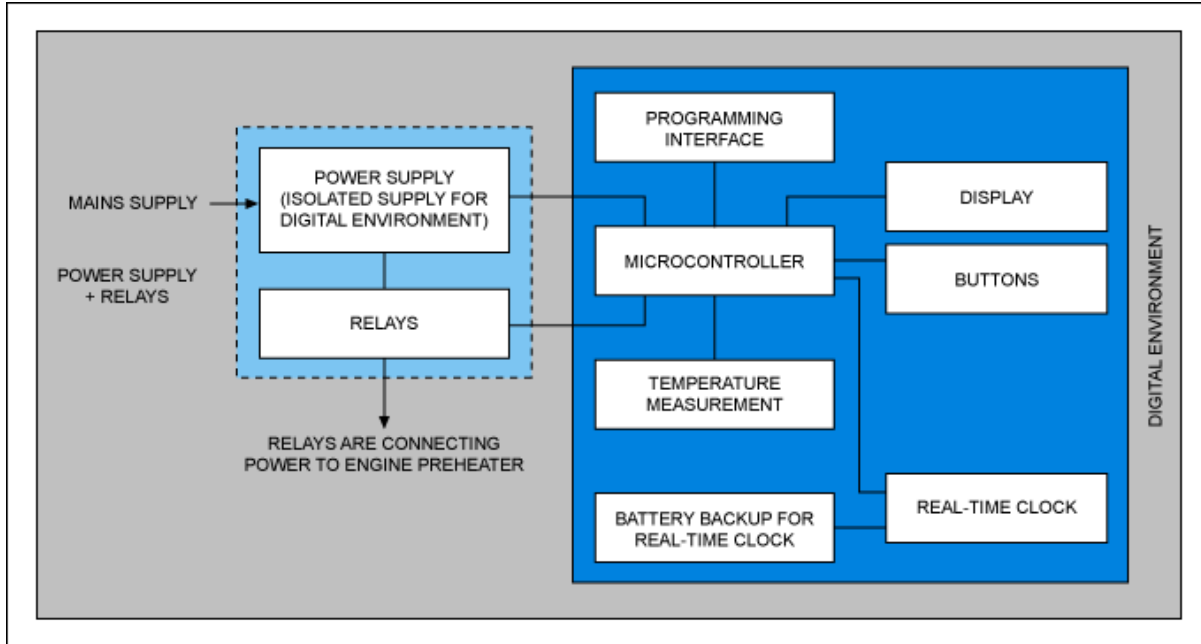
Figure 4. A block diagram for a temperature-based heating-system.

System Schematics

The system described in this article was compiled using two PCBs: One for the power supply and relays, and the second for the processor (digital) environment. A power supply and relay board schematic is shown in **Figure 5**.
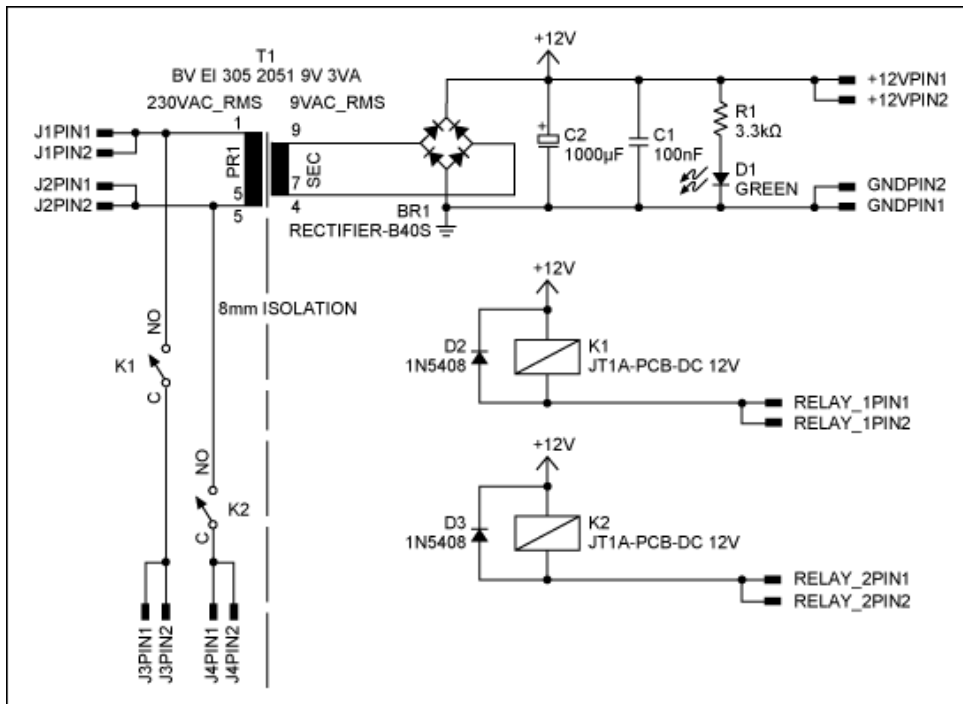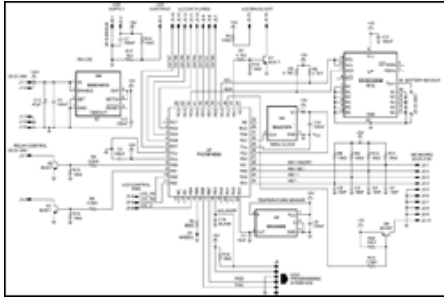

Figure 5. A power supply and relay board schematic.

Power supply and relay board connects mains supply to relays and provides isolated, rectified, and preregulated 12V supply voltage to the processor board. The processor environment schematic is shown in **Figure 6**.

Figure 6. The processor environment schematic.

DC-DC conversion from 12V to 5V is done using a linear low-dropout voltage regulator like the MAX16910, because it has built-in thermal and short-circuit protection. The system microcontroller is a Microchip PIC18F4520 running at an 8MHz clock frequency. Microcontroller clocking is completed using a very small (SC-70) silicon oscillator like the MAX7375, which has an excellent temperature coefficient and extremely low jitter.

Ambient temperature is measured with an analog-output temperature sensor. The MAX6605 has low output impedance (240Ω), so it can be connected directly to the microcontroller analog-to-digital converter (ADC) without an external buffer amplifier.

The system needs to know the exact time, so a real-time clock (RTC) is used. The Maxim DS3232 RTC has an internal oscillator and EEPROM. In this system, EEPROM is used to store timing parameters, so system information can be fully restored if a power cut event happens. The RTC is accessed using an I²C interface. Backup battery ensures that the system keeps accurate time information, even during a power outage. Additionally, since relays in this system require a 12V coil voltage, relay driving is done with NPN transistors Q2 and Q3.

Buttons (ON/OFF, SET, PLUS, and MINUS) are connected to the microcontroller with connector J2. The system display is a 4x20-character LCD and is connected to the microcontroller with connector J5. An LCD backlight is driven on/off by transistor Q1. Connector J4 programs and debugs the microcontroller. Transistor Q4 is only gives 5V output voltage, if needed. The 5V output voltage can be used, for example, to drive an external LED to indicate if the system has connected electricity to the engine preheater.

System PCBs

System PCBs are shown in **Figures 7** to **9**.
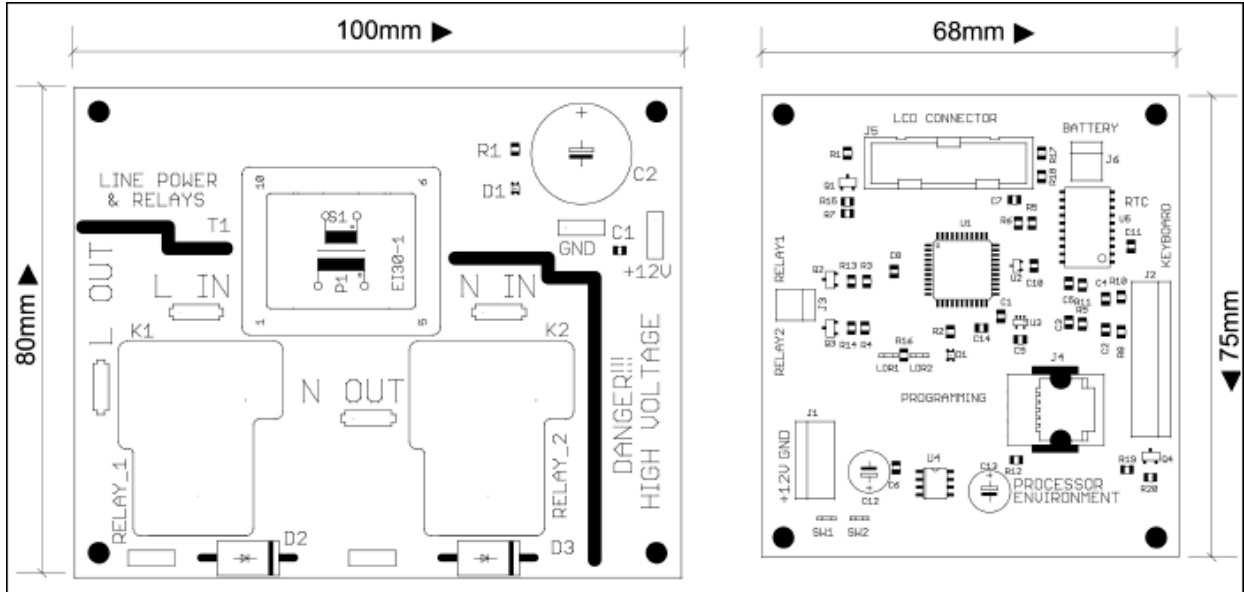
Figure 7. Component placements. The power supply and relay board is on the left side, and the processor board is on the right.
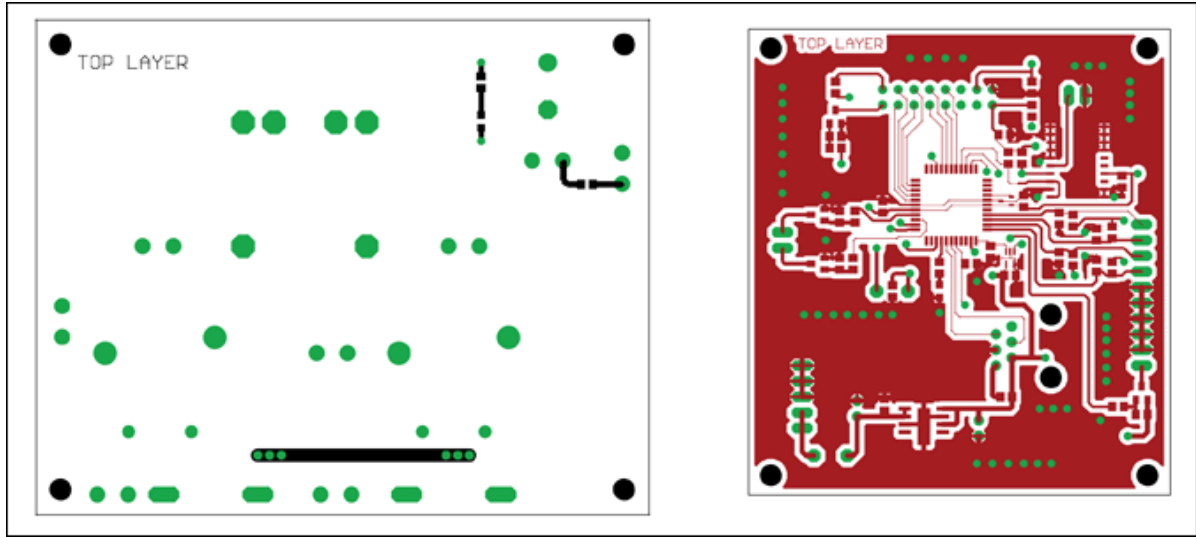
Figure 8. Top-side layers.
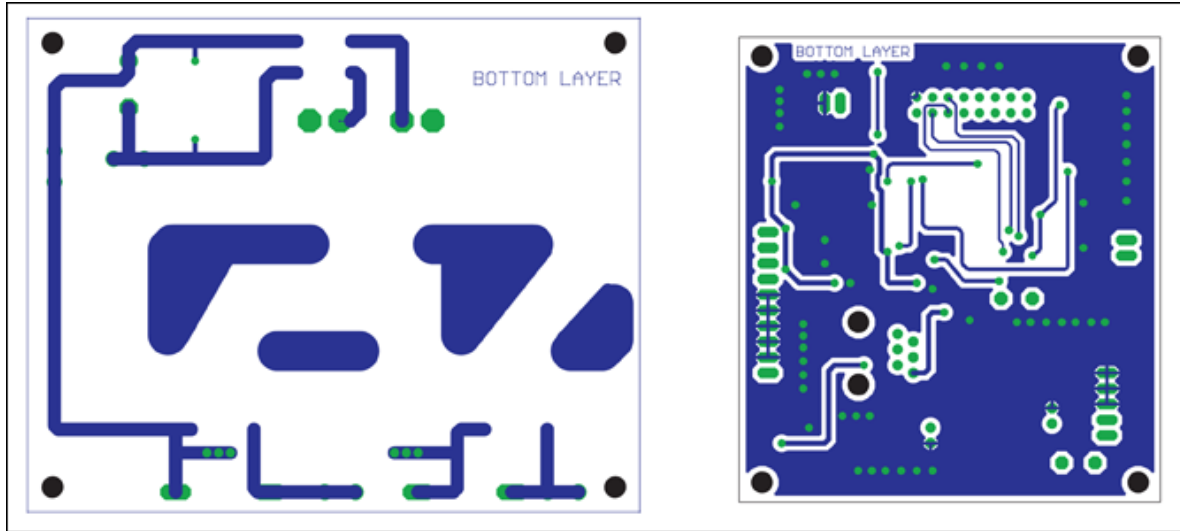
More detailed image. (PDF, 3.5kB)
Figure 9. Bottom-side layers.

PCBs are mounted inside waterproof industrial enclosure with IP65-IP67 protection class. A fully functional and assembled system is shown in **Figures 10** and **11**.

Figure 10. A fully assembled and functioning system in the real world.

Figure 11. A functional system with an open front cover.

User Interface

The user interface consists of a 4x20-character LCD and four buttons: ON/OFF, SET, PLUS, and MINUS. The ON/OFF button manually connects or disconnects electricity to/from the engine preheater. The SET key accesses the settings for programming the desired engine start time, while PLUS and MINUS increase/decrease values and parameters. LCD row 1 displays date, time, and ambient temperature. Row 2 displays whether the starting time has been set. Row 3 displays the preordained starting time. Row 4 displays if heating is on or off. The user interface is shown in **Figure 12**.
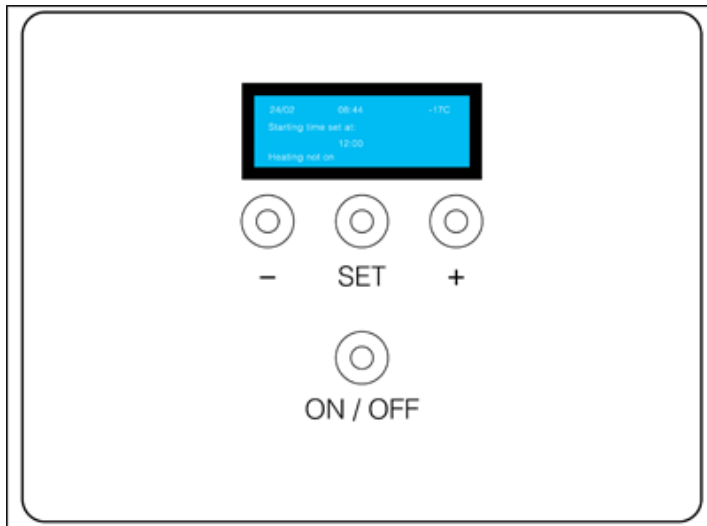
More detailed image. (PDF, 870kB)
Figure 12. The user interface.

Part Lists

The power board and processor board part lists are shown in **Table 1** and **Table 2**, respectively.

Table 1. Power Board Part List			
Part	**Value**	**Package**	**Description**

+12V connector	4.8mm Abiko connector		Connector
GND connector	4.8mm Abiko connector		Connector
BR1	B40S	B40S	Rectifier
C1	100n/50V	0805	Capacitor
C2	1000µ/35V	E7.5-16	Electrolytic capacitor
D1	Green LED	0805	LED
D2–D3	1N5408	DO210-15	Diode
K1–K2	JT1A-PCB-DC12V	JT1A	12V/16A relay
R1	3k3 ohm/1%	0805	Resistor
Relay_1 connector	4.8mm Abiko connector		Connector
Relay_2 connector	4.8mm Abiko connector		Connector
T1	BV EI 305 2051	EI30-1	9V 3VA rectifier
J1–J4	6.3mm Abiko connector		Connector

Table 2. Processor Board Part List

Part	Value	Package	Description
C1–C5	10nF/50V	0805	Capacitor
C6–C11	100nF/50V	0805	Capacitor
C12	47µF/35V	E2.5-7	Electrolytic capacitor
C13	100µF/10V	E2.5-7	Electrolytic capacitor
C14	Blank	0805	Capacitor
D1	Green LED	0805	Green LED
J1	22-23-2051 Header	2.54mm pitch	Molex 5-pin connector
J2	22-23-2101 Header	2.54mm pitch	Molex 10-pin connector
J3, J6	22-23-2021 Header	2.54mm pitch	Molex 2-pin connector
J4	520258-3	6-pin modular	Amp modular connector
J5	2516-6002UB	16-pin straight	3M ribbon cable connector
Q1–Q3	BC817B	SOT-23	NPN transistor
Q4	BC857B	SOT-23	PNP transistor
R1	100Ω/1%	0805	Resistor
R2	680Ω/1%	0805	Resistor
R17	1kΩ/1%	0805	Resistor
R3–R4, R19	2k2Ω/1%	0805	Resistor
R5–R7	4k7Ω/1%	0805	Resistor

R8–R15, R20	10kΩ/1%	0805	Resistor
R18	15kΩ/1%	0805	Resistor
R16	220kΩ/1%	0805	Resistor
U1	PIC18F4520-E/PT	TQFP-44	Microchip Microcontroller
U2	MAX7375AXR805+	SC70-3	Maxim Silicon Oscillator
U3	MAX6605MXK+	SC70-3	Maxim Temperature Sensor
U4	MAX16910CASA8/V+	SO8-EP	Maxim LDO
U5	DS3232SN#	SO-20	Maxim Real Time Clock

The LCD is 4x20 characters. Any HD44780-compatible LCD display will work. Check the LCD backlight polarity before connecting it to the PCB, because manufacturers sometimes use different pins. The backup battery is 2 × 1.5V AA batteries in series, and the buttons are 4 × normally open type.

Summary

This article explains how to design hardware for a heating system that connects electricity to an engine preheater, based on ambient temperature and a preordained engine starting time. This system can also be used for other purposes, such as turning on a storage heater if the ambient temperature falls below a preordained value.

Related Parts		
DS3232	Extremely Accurate I²C RTC with Integrated Crystal and SRAM	Free Samples
MAX16910	200mA, Automotive, Ultra-Low Quiescent Current, Linear Regulator	Free Samples
MAX6605	Low-Power Analog Temperature Sensor in SC70 Package	Free Samples
MAX7375	3-Pin Silicon Oscillator	Free Samples

More Information
For Technical Support: http://www.maximintegrated.com/support
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