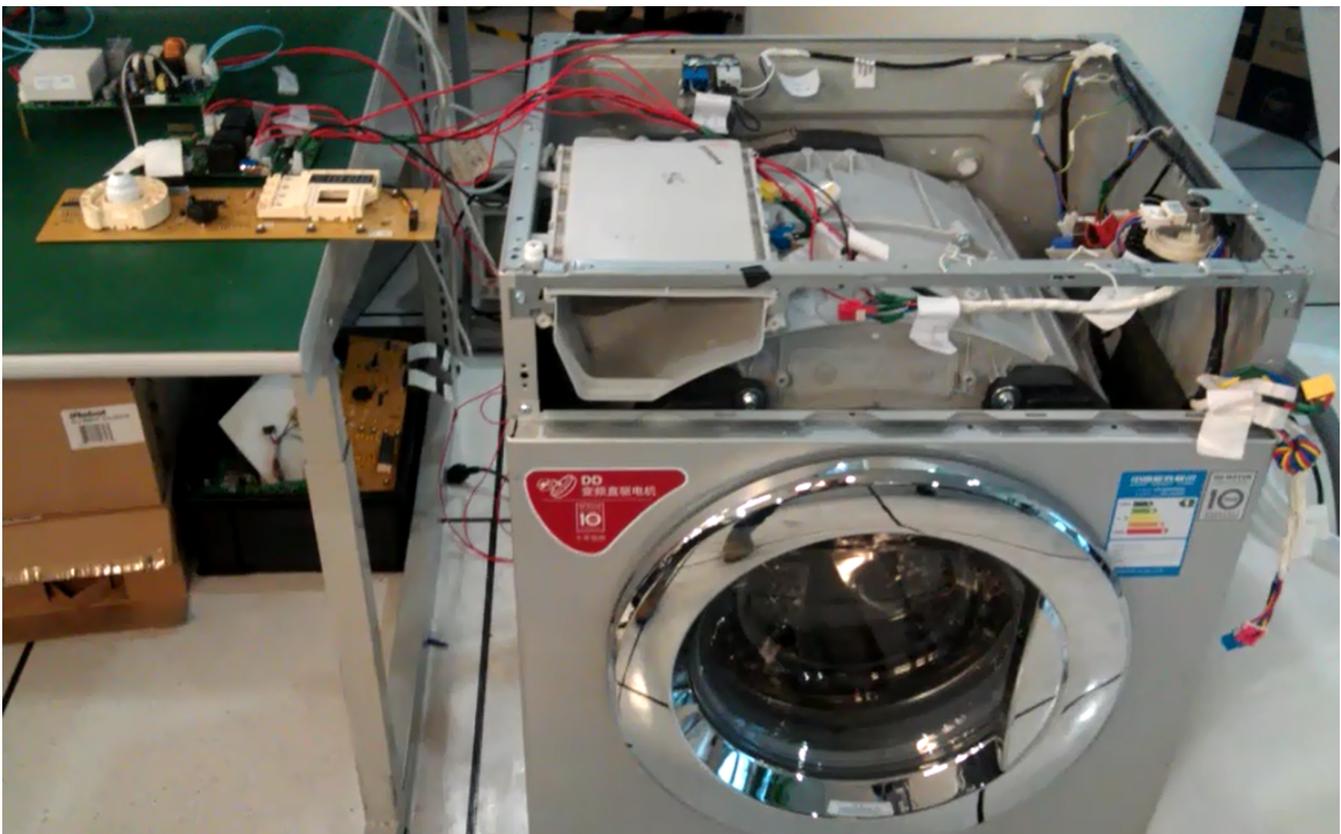


## ***Washing Machine Control Reference Design User's Guide***

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This solution is designed for the inverter front-loading washing machine and based on MSP430F5418 (used for the main control system) and TMS320F28027F (used for motor control). This machine is designed to implement direct drive variable frequency (DDVF) motor control and whole washing process control. Additionally, the design detects basic failures such as filling failure, draining failure, and motor failure.



**Figure 1. Picture of Reference Design Platform**

## 1 System Block Diagram

The hardware includes three parts: the main control board, the motor control board, and the user interface board. The main control board manages the washing process. This board gets feedback from various sensors (NTC, water pressure sensor, and so on) and controls the action of all electric components (door lock, heater, valve, pump, and motor) according to the washing logic.

The motor control board controls the DDVF motor and communicates with main control board by UART. This board receives commands from main control board and sends back the status of motor.

The user inference board is the human interface between the user and washing machine. This board reads the user's input and shows the status of the washing machine with LED lights. The user interface board is controlled by the main control board directly through matrix scanning.

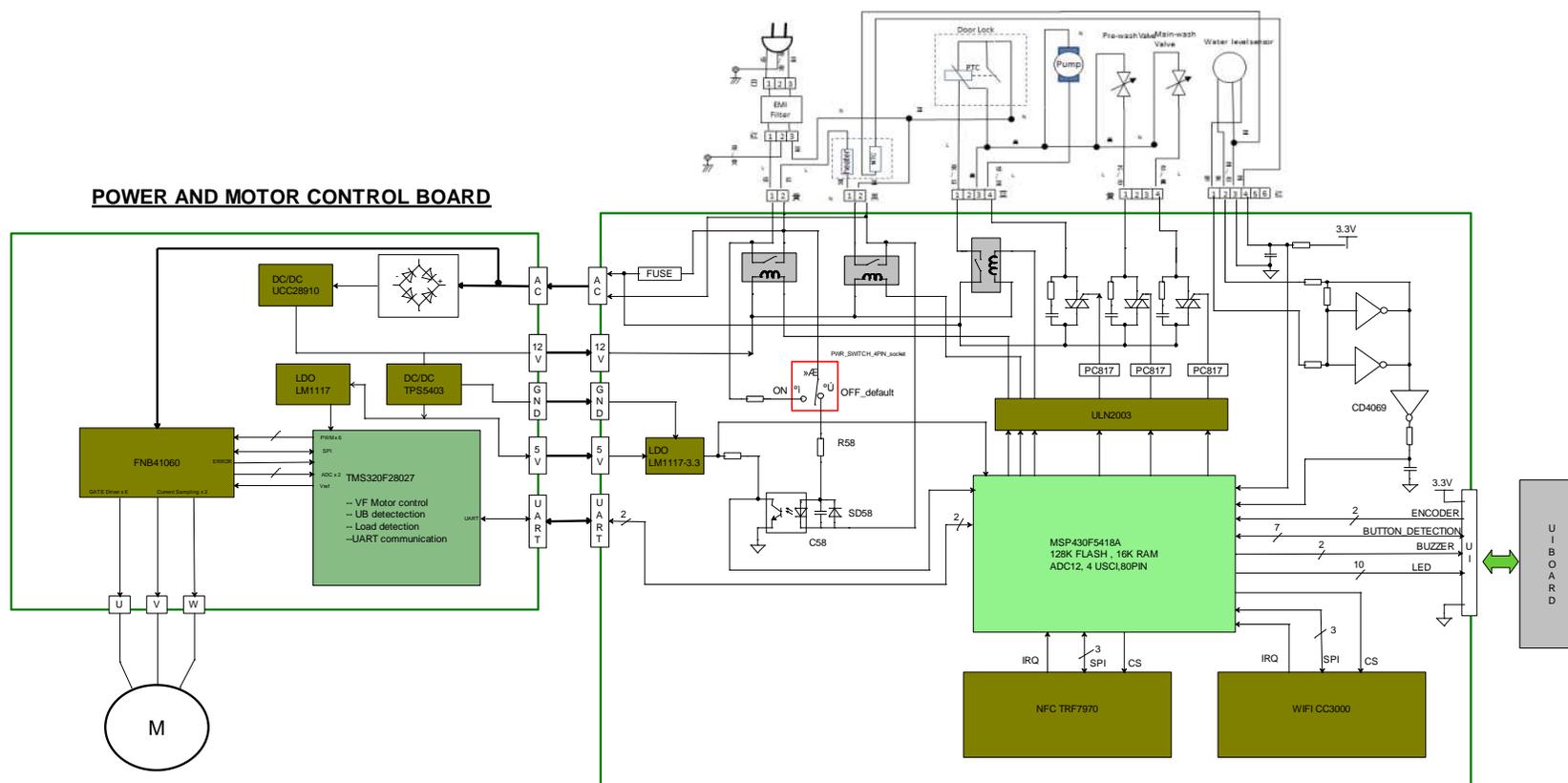


Figure 2. System Block Diagram

## 2 Hardware

This section defines the interfaces of the main control board and the motor control board.

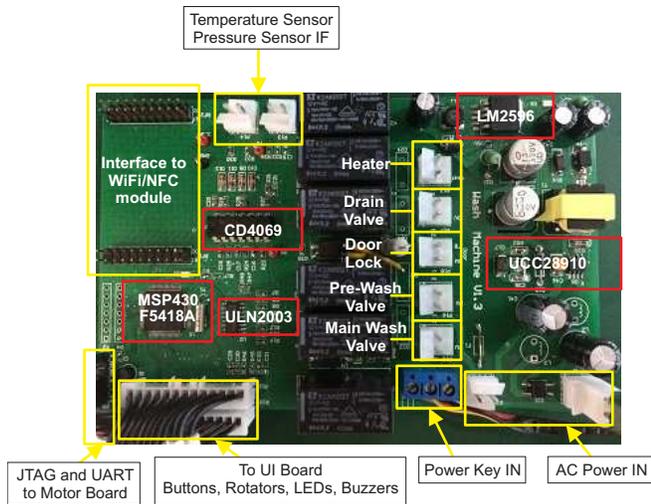


Figure 3. Main Control Board

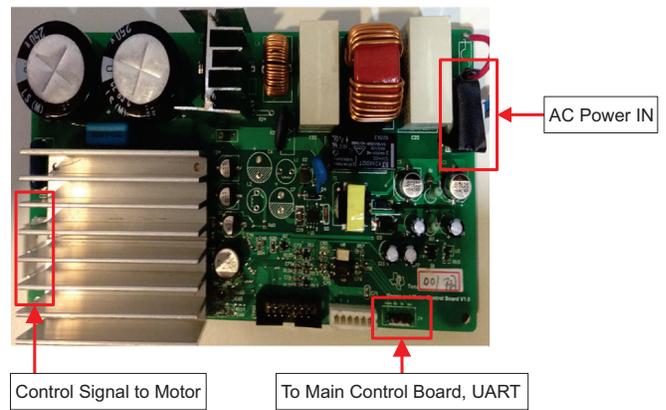


Figure 4. Motor Control Board

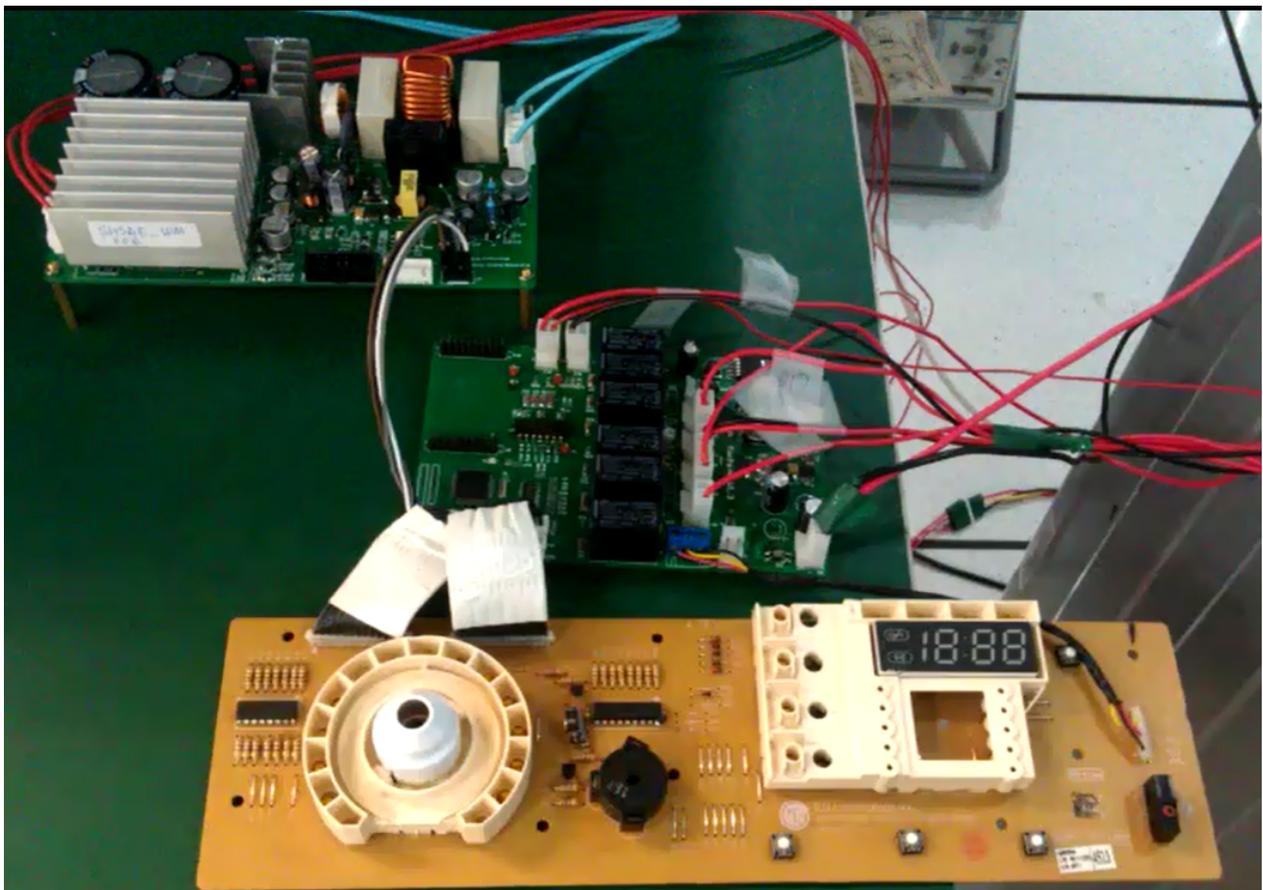


Figure 5. System Connection

### 3 Software State Machine

This washing machine has the following states in its life cycle: Standby, Selection, Execution, Pause, BrownOut, Delay, End, Test, and Failure.

- **Standby:** When the washer is power on, it goes to Standby state. The door is unlocked.
- **Selection:** After the user selects a wash program by turning the knob, the machine goes to the Selection state. In this state, the user can choose the washing program and set the spin speed, washing temperature, and so on.
- **Execution:** Once the user presses the *Start* button, the machine moves to the Execution state, starting the washing program. The door is now locked.
- **Pause:** The machine switches to a Pause state when pressing the *Pause* button during the Execution state. The user can change the configuration of washing program.
- **BrownOut:** The machine moves to this state when the main line voltage is too high or too low. The washing program will resume when the voltage is in a normal range again.
- **Delay:** This state starts a countdown and goes to Execution automatically when the time expires.
- **End:** Once the washing program finishes, the display reads *END*. Changing the knob or pressing the button goes back to the Selection state.
- **Test:** Go to the Test state by pressing the *Speed* and *Temperature* buttons at the same time.
- **Failure:** If any failures occur, the washing program stops and displays a failure code.

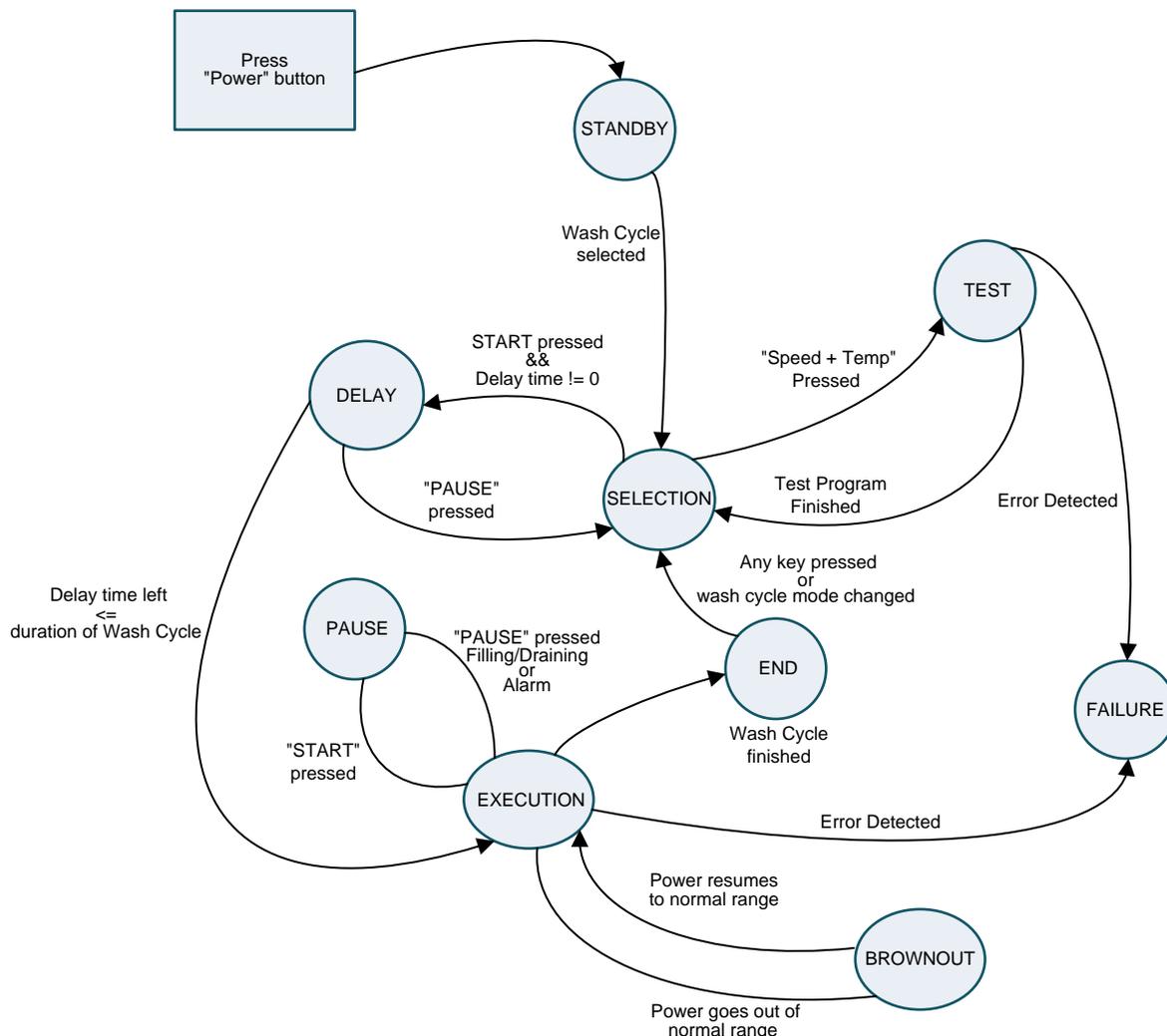


Figure 6. State Machine

## 4 Motor Control Features

- InstaSPIN™-FOC**  
 In this solution, we use [TI InstaSPIN-FOC technology](#) in the motor control. You can find The following is one of key performance of the InstaSPIN estimator for the sensorless PMSM control. Block the motor when the motor runs with a sensorless closed loop, and then release it. The motor can continue to run with the same direction and speed before the block.
- Agitate Washing**  
 The current of agitate washing is continued when motor change direction. The washing machine does not stop the motor and then restarting in the opposite direction; the machine changes the speed reference from positive to negative repeatedly during the close loop control.

## 5 Motor Control Test Data

Connect the system as described in [Section 2](#), and run the following tests.

### 5.1 Startup Test without Load

- Keep the drum empty, close the door, and select the *Single Spin* program (the spin profile is preloaded in the software).
- Press the *Start* button.
- Observe the current when the motor starts to accelerate.

As [Figure 7](#) shows, the current changes smoothly when the motor starts to run and accelerate.

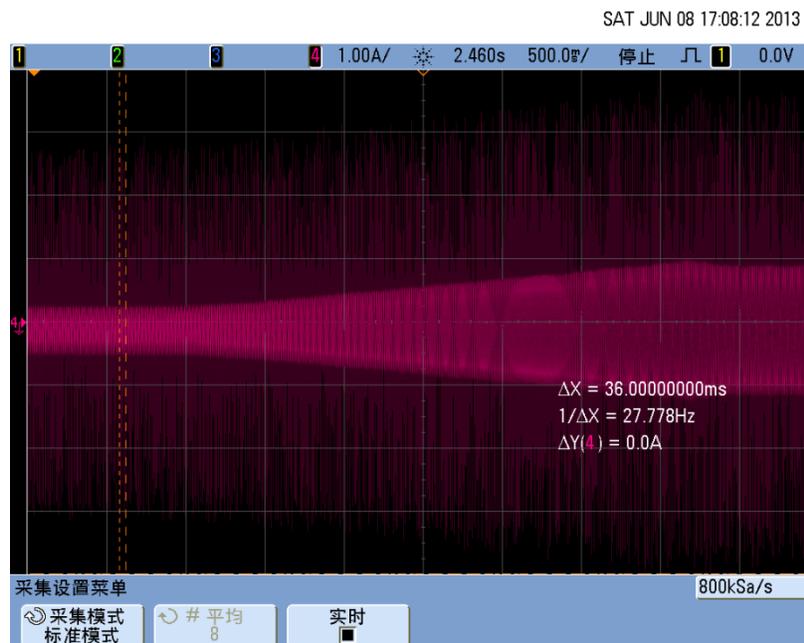


Figure 7. Acceleration from Low Speed without Load

## 5.2 Startup Test with Load

1. Put a light load in the drum, close the door, and select one washing program.
2. Press the *Start* button.
3. Test the current when the motor speed increases from 0 rpm.

Figure 8 displays a readout of a smooth start-up. However, when the load becomes too heavy, the vibration of current can be observed occasionally, which the software can improve.



**Figure 8. Start-up with Load**

### 5.3 Agitation Test without Load

1. Keep the drum empty, close the door, and select one washing program.
2. Press the *Start* button.
3. Test the current when the motor moves forward and backward.

Figure 9 displays the consistent current when the motor changes direction.

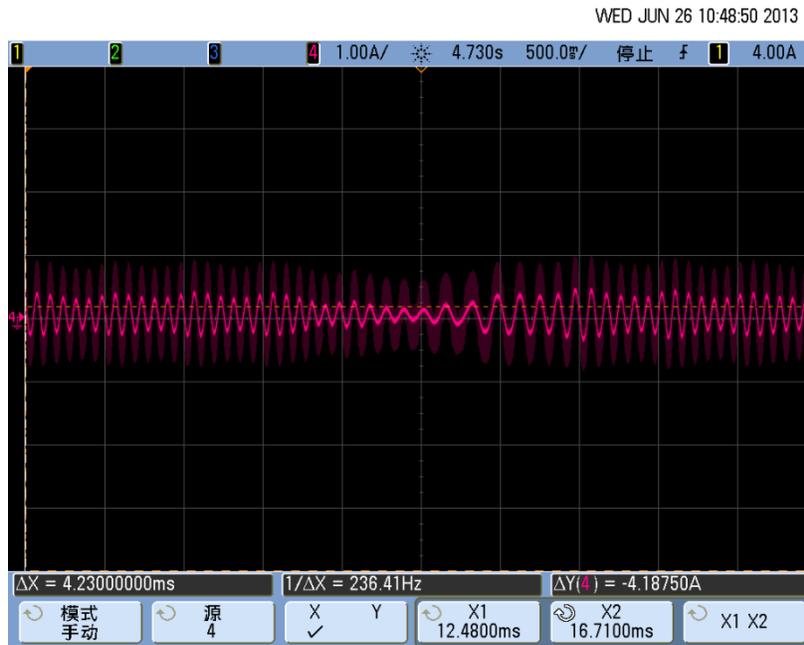


Figure 9. Reversing without Load

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Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
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