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4-20mA Output for TMR Liquid-Level Sensors

Aug 2021

About MDT

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- Founded in 2010, first volume supplier of TMR sensors
- Fully owned advanced TMR sensor fab for volume production
- Over 300+ patents on TMR sensor design, fabrication and applications
- Key differentiators:
  cutting-edge technology; mass production capacity; strong IP portfolio; expertise in the field.

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TMR Switch: Features

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- 200nA Ultra-low power
  - 1.5μA in continuous operation (1st gen)
  - 200nA in fast 50Hz switching clock (2nd gen)
- High-speed operation
  - 1kHz frequency response continuous (1st gen)
  - 50Hz switching clock (2nd gen)
- High sensitivity
  - 2 ~ 50 Gauss (customizable)
- Temperature stability
  - -40 ~ 125 °C
- Versatility
  - Omnipolar, bipolar, unipolar
  - Low and high voltage
  - CMOS and open-drain
  - Supplied to many industries in high volumes (~36 million pcs in 2019)

	MDT 1st Gen	MDT 2nd Gen	Competition
Technology	TMR	TMR	AMR/GMR/TMR
Speed	Continuous	50Hz switching	2~10Hz switching
Power	1.5μA	200nA	100/200/350nA
Key Products	TMR1202/1302/1340	TMR1162/1262/1362	

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Application: Liquid-level Sensors

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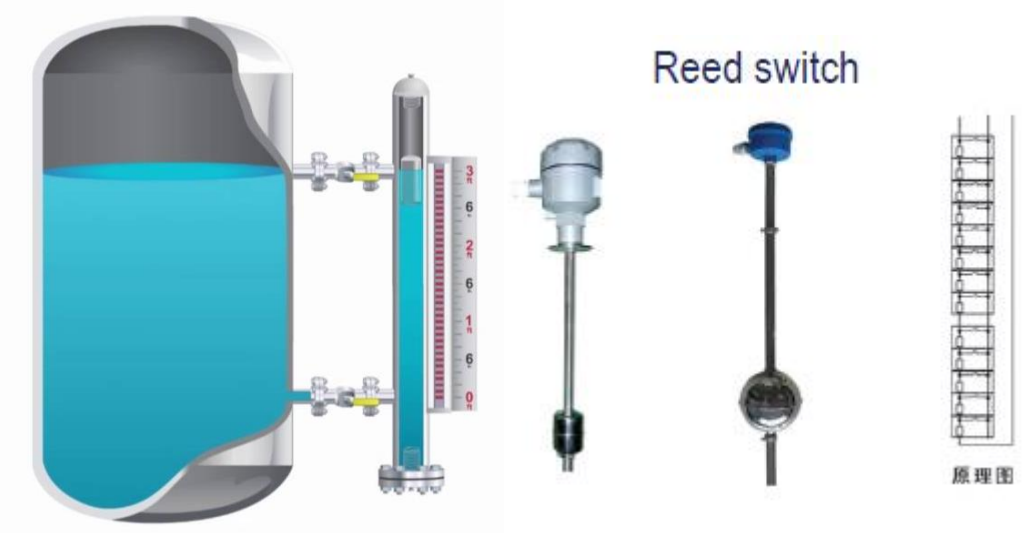
- MDT products
  - TMR1340 omnipolar switch with open-drain
- Benefits
  - Flexible design with open-drain output
  - 1.5μA ultra-low power, can support >1000 sensors in a TMR ladder
  - SMT compatible assembly process
  - High reliability vs. Reed
  - Cut or join in any length
  - Easy storage, transport, handling with flex PCB



TMR switch can replace Reed switch for liquid-level sensing with higher reliability and streamlined SMT assembly process.

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3-wire Measurement Principle

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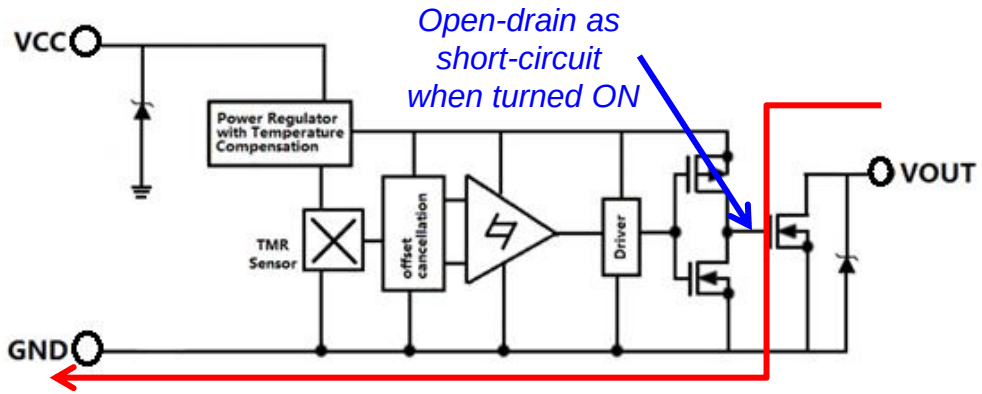
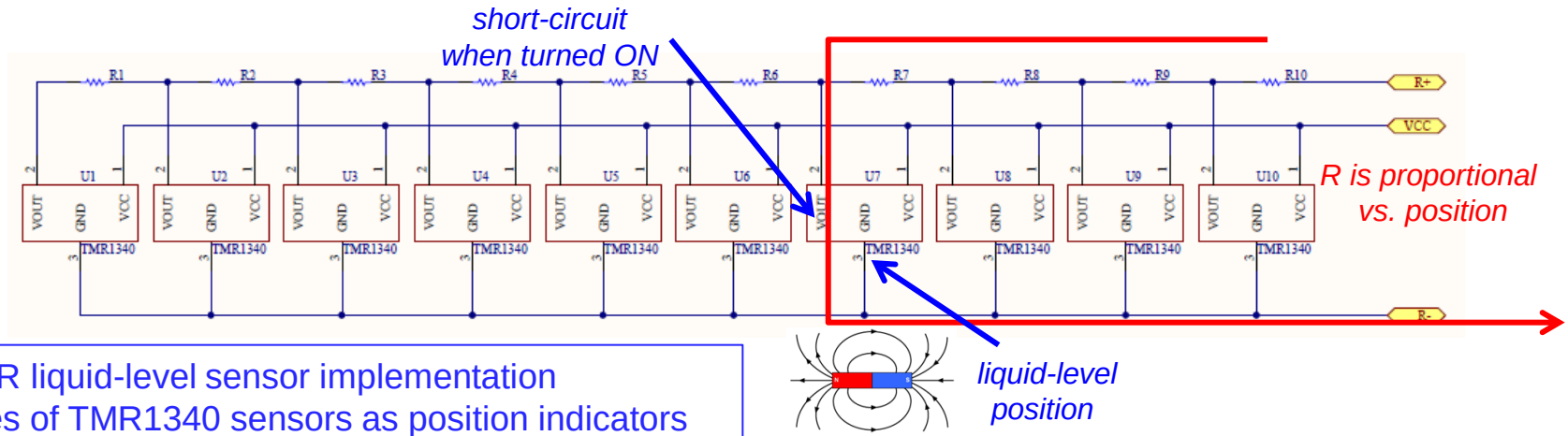


TMR1340 with open-drain output – Vout and GND will be short-circuited when the TMR switch is turned ON.



3-wire TMR liquid-level sensor implementation
- a series of TMR1340 sensors as position indicators
- Vcc powered by a common voltage source in parallel
- Vout connected to a resistor network in serial

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Resistance vs. Position

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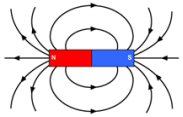
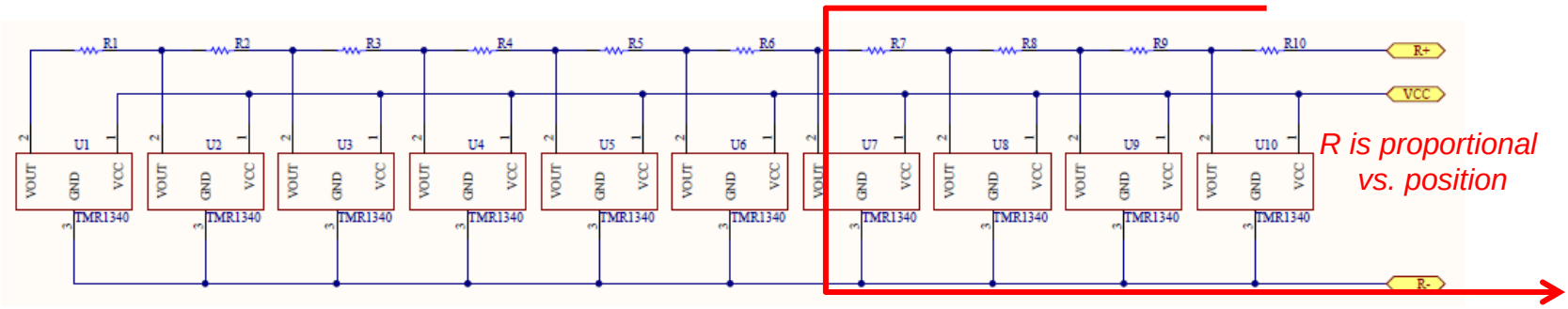
liquid level position ⟺





R is proportional vs. position

R=R1+R2+R3+R4+R5+R6+R7+R8+R9+R10

R=R2+R3+R4+R5+R6+R7+R8+R9+R10

R=R3+R4+R5+R6+R7+R8+R9+R10

R=R4+R5+R6+R7+R8+R9+R10

R=R5+R6+R7+R8+R9+R10

R=R6+R7+R8+R9+R10

R=R7+R8+R9+R10

R=R8+R9+R10

R=R9+R10

R=R10

All resistors are the same in TMR liquid-level sensors, resulting in the resistance value being proportional to the position of the magnet.

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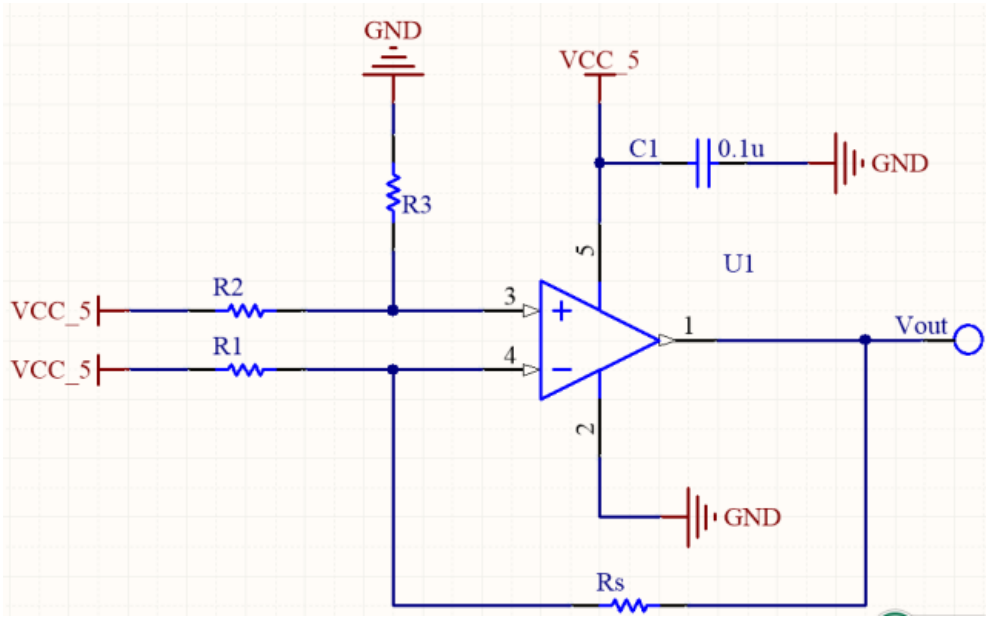
Converting Resistance to Linear Voltage

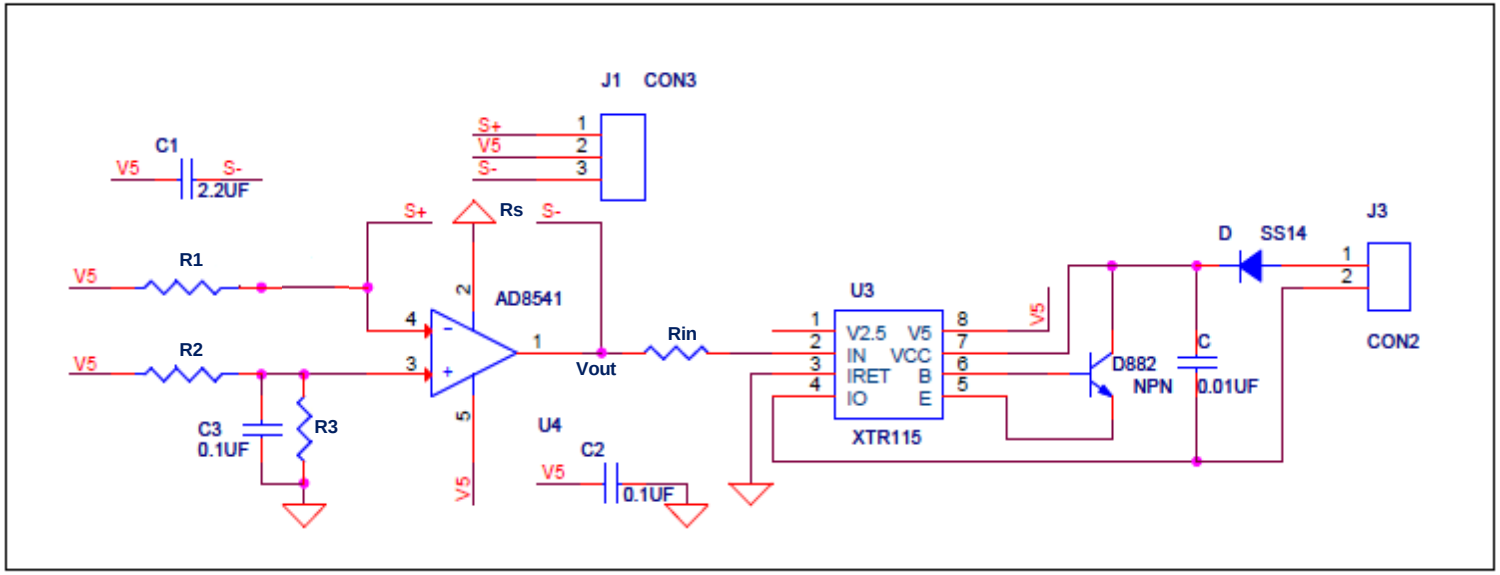


An op-amp can create a linear output voltage vs. the sensor's resistance Rs (linear vs. position).
According to the virtual-short condition of an op-amp:

$$Vout = \frac{R3}{R2+R3} * Vcc - \frac{R2}{R2+R3} * \frac{Rs}{R1} * Vcc$$

Then Vout is linear vs. position.

Converting Voltage to Linear Current



According to the XTR115 current transmitter –

Iout = 100 * Iin
Iin = Vout / Rin

Since Vout is linear vs. position, then Iout of XTR115 is also linear vs. position.

4-20mA Reference Design (Example of 300 TMR sensors)

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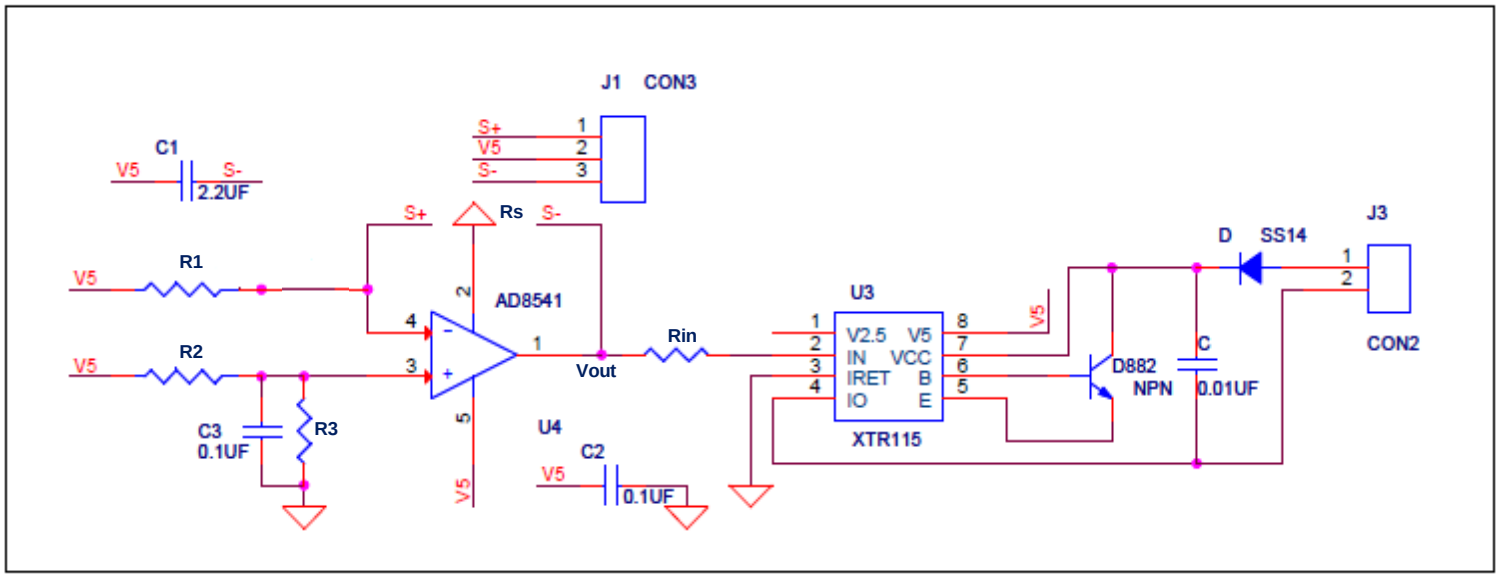

Reference design setup:

- 300 TMR sensors, and R = 10 Ohm for each sensor.
- Rs will vary from 0 to 3k Ohm, and Iout will vary from 4mA to 20mA accordingly.
- Then Iin will vary from 40uA to 200uA.
- Take Rin = 15k Ohm, and Vout should vary from 0.6V to 3.0V (user can pick other values).
- Vcc = 5.0V

4-20mA Reference Design (Example of 300 TMR sensors)

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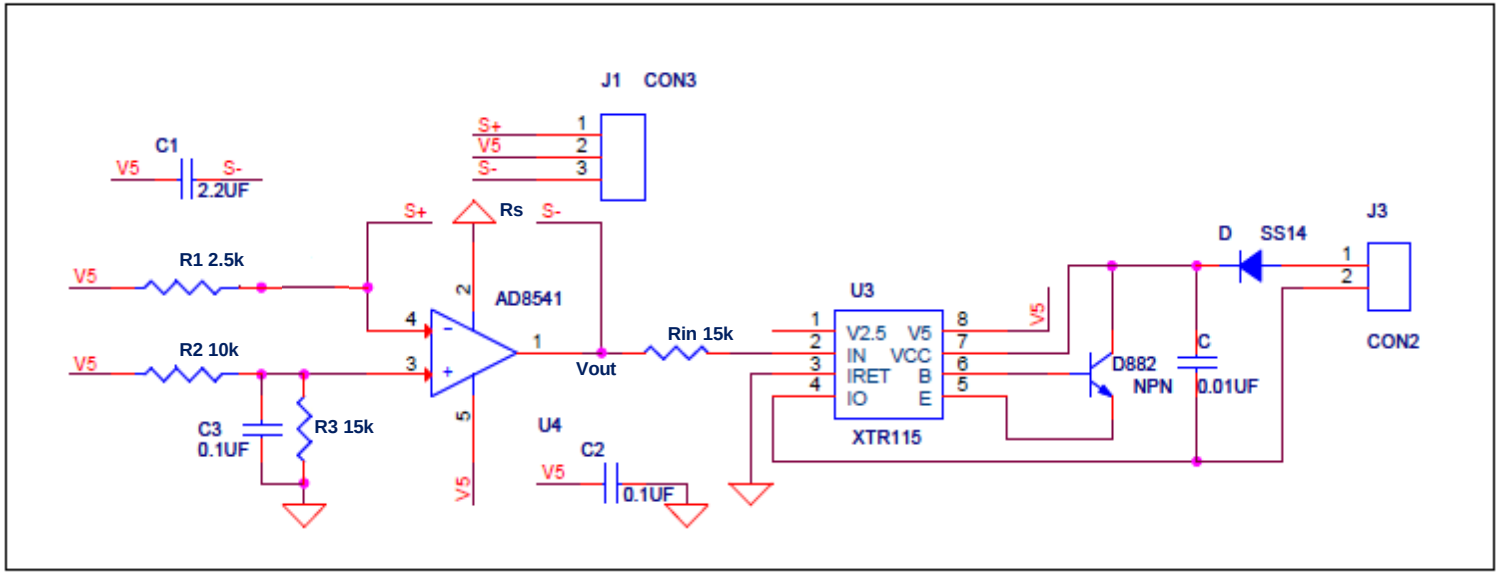

From: $$Vout = \frac{R3}{R2+R3} * Vcc - \frac{R2}{R2+R3} * \frac{Rs}{R1} * Vcc$$

Rs=3.0k: $Vout(min) = \frac{R3}{R2+R3} * Vcc - \frac{R2}{R2+R3} * \frac{Rs}{R1} * Vcc = 0.6V \Rightarrow \frac{R1}{Rs} = \frac{5}{6} \Rightarrow$ R1=2.5k

Rs=0: $Vout(max) = \frac{R3}{R2+R3} * Vcc = 3.0V \Rightarrow \frac{R2}{R3} = \frac{2}{3} \Rightarrow$ R2=10k, R3=15k

(choose from the same range of R1)

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Summary

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- TMR liquid-level sensors can be designed with a 4-20mA linear output.
  - Reference design is based on op-amp and XTR115.
  - Output current in 4-20mA is linear vs. liquid level position.
  - R1/R2/R3 must be adjusted for different configurations (length, resistance, and etc.)
- Many customers use digital solutions instead.
  - Liquid level is calculated by software.
  - MCU can output any signal, 4-20mA or RS485.
  - Same solution works for all configurations.

Thank you

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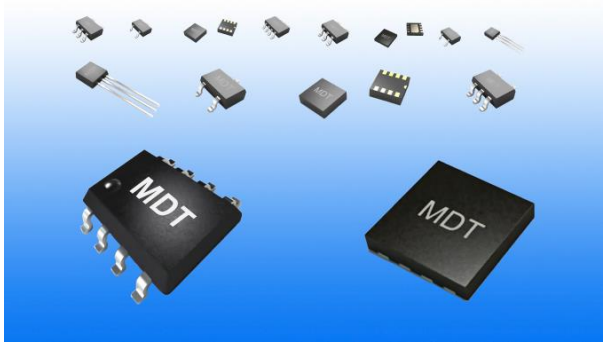

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