MotorKit Nu-KE-MTR_HV001
User Manual

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1. OVERVIEW

MotorKit Nu-KE-MTR_HV001 is an inverter board for High voltage motor control. By connecting this board to the inverter control MCU board Nu-KT-MTR_xxx (xxx:MCU parts number), it is possible to develop motor control applications according to each NTCJ microcomputer.

[Spec]

- Product name : High Voltage Inverter Board
- Board product No. : Nu-KE-MTR_HV001
- Operating input voltage range : AC 220Vrms / AC100Vrms
- Max. input power : 2.2kW@AC220Vrms input / 1.0kW@AC100Vrms input
- Rated output power : 2kW@AC220Vrms output
- Rated output current : AC 10A(effective value)
- Switching Frequency：2kHz～20kHz
- Dead time : 1.0 us or more
- Current detection method : 1 shunt / 3 shunt method
- PWM logic : Active High logic for both upper and lower arms
- DC bus voltage detection : Detection by resistance division（5V to 445V）
- 1 Shunt resistor : 22mΩ*2 (parallel)
- 3 Shunt resistor : 10mΩ
- Current detection : Voltage detection by shunt resistance
- Overcurrent detection function : Detection by comparator
- Connector : MCU board connection, Encoder, Hall sensor
- Switch : DIP Switch (4)
- LED : LED×2

2. HARDWARE CONFIGURATION

2.1 Top View

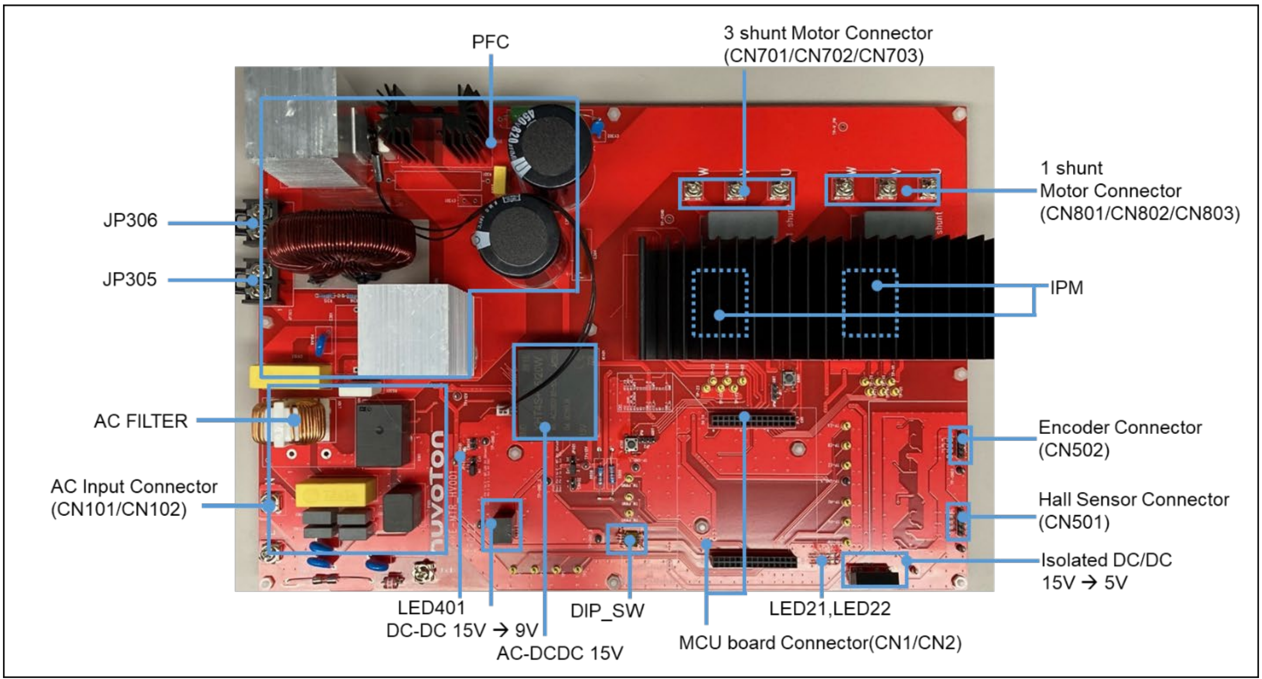


Figure 2-1 Top View of Nu-KE-MTR-HV001

Figure 2-1 shows the main components and connectors from the top side of Nu-KE-MTR_HV001. The following lists components and connectors from the top view:

- Motor Drive (IPM)
- Over Current Detect
- MCU board Connector(CN1/CN2)
- AC Input Connector (CN101/CN102)
- Earth(CN103)
- 3 shunt Motor Connector(CN701/CN702/CN703)
- 1 shunt Motor Connector(CN801/CN802/CN803)
- PFC
- AC Filter
- Encoder
- Hall sensor
- Input voltage selection jumper (JP305/JP306)
- DIP Switch
- LEDs(LED21/LED22)

2.2 Bottom View

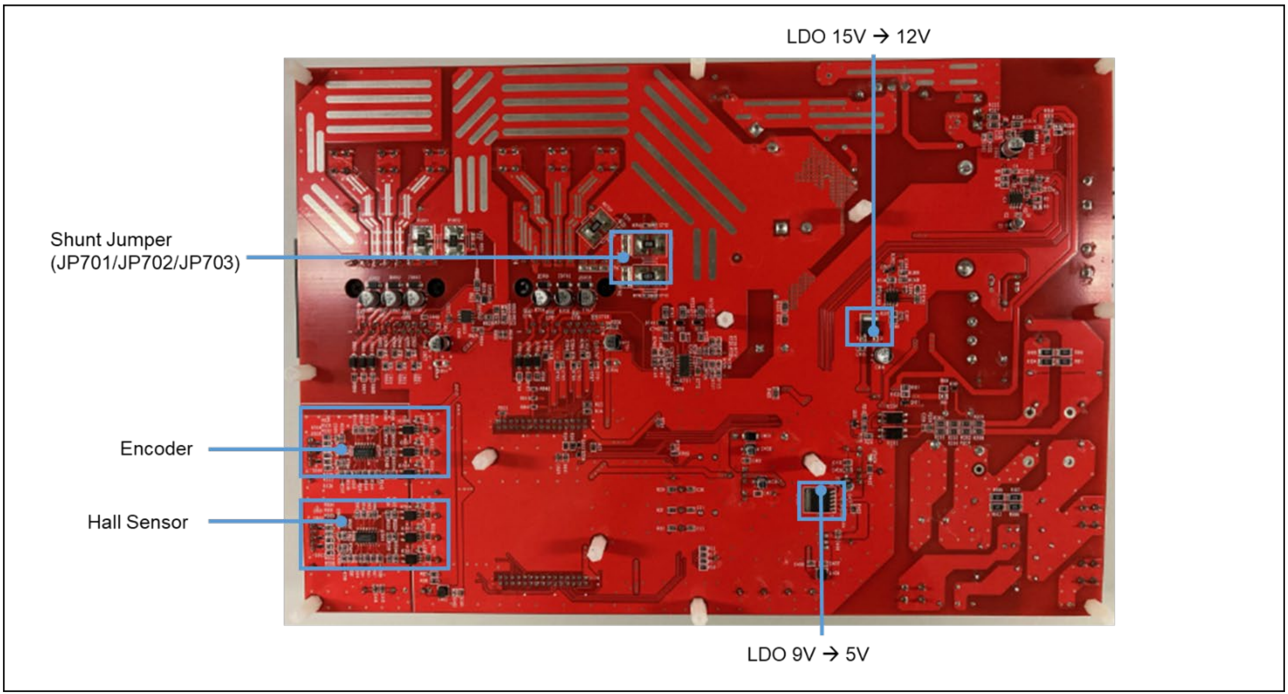


Figure 2-2 Bottom View of Nu-KE-MTR_HV001

Figure 2-2 shows the main components and connectors from the bottom side of Nu-KE-MTR_HV001.

The following lists components and connectors from the bottom view:

- Shunt Jumper(JP701/JP702/JP703)
- Encoder
- Hall Sensor
- LDO (15V → 12V)
- LDO (9V → 5V)

2.3 Voltage Generator Circuit

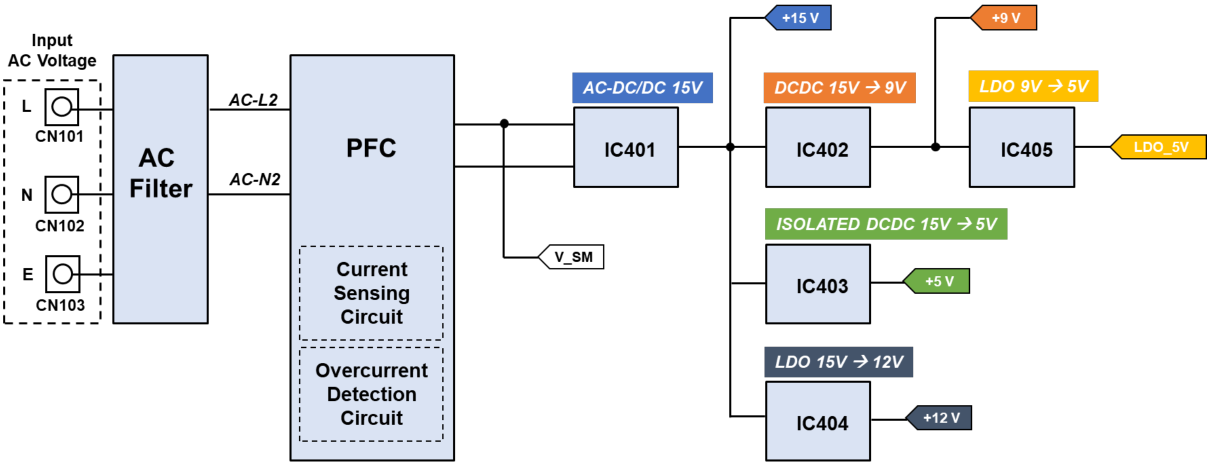


Figure 2-3 Voltage Generator Circuit

Nu-KE-MTR_HV001 generates the following voltages from the main power supply.

■Main power supply (AC)

Connector	Description
CN101/CN102 CN103	AC voltage input Input voltage : AC 220Vrms / AC100Vrms

■Output voltage

Voltage	Description
V_SM	・Input to DCDC converter ・DC bus voltage
15V output (+15V)	・Input to 9V Regulators ・Input to Isolated Module DCDC Converter ・Supply to peripheral circuits ・Supply to power relay ※Please use when replacing the power relay with a 15V product.
9V output (+9V)	・Input to 5V Regulators
5V output (LDO_5V)	・Supply to microcomputer ・Supply to peripheral circuits
5V output (+5V)	・Supply to Hall-sensor and Encoder circuits
12V output (+12V)	・Supply to power relay

2.4 Inverter Control Circuit Block

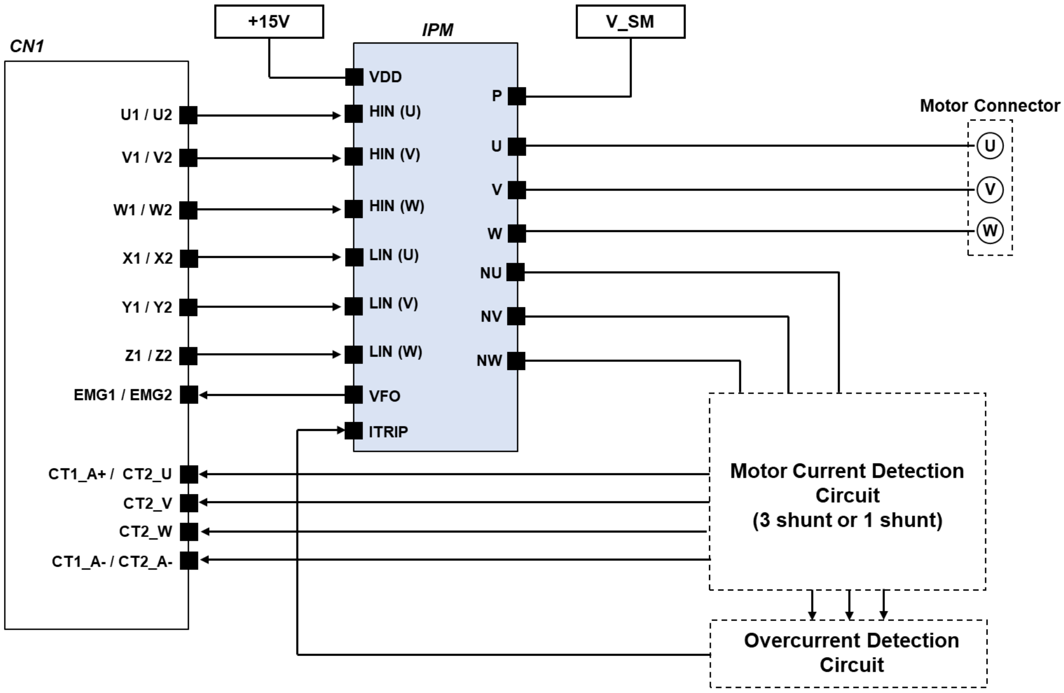


Figure 2-4 Inverter Control Circuit

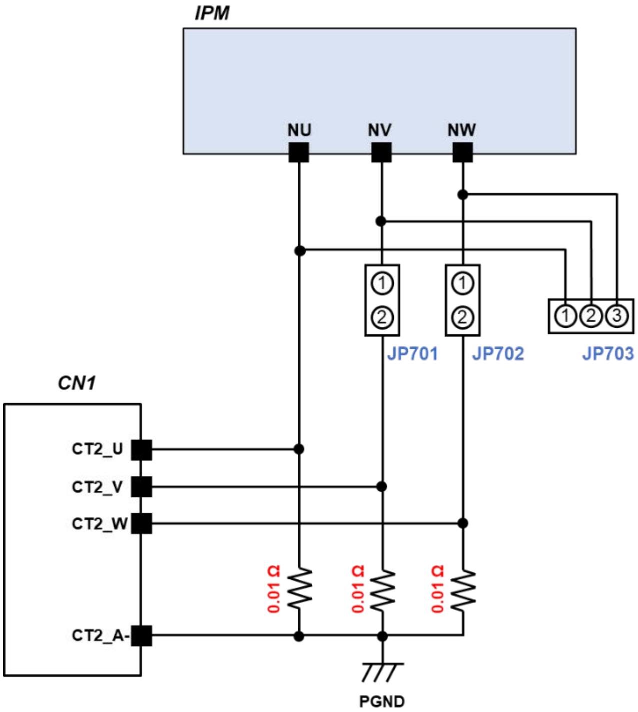
Figure 2-4 is a schematic diagram of the inverter control circuit.

The Nu-KE-MTR_HV001 has two inverter control circuits that the 3-phase complementary PWM timer output from the microcontroller controls the intelligent power module(IPM) and drives the motor.

The inverter control circuit has a Motor current detection circuit that measures the current of each phase of U, V and W with shunt resistor.
One is the 3 shunt current detection method, and the other is 1 shunt current detection method.
The circuit on the 3-shunt side can be switched to 1-shunt.
Please refer to 2.5 Motor Current Detection Circuit for details.

The inverter control circuit has a overcurrent detection circuit that detects the overcurrent event from shunt current of each phase of U, V, and W.
Please refer to 2.6 Overcurrent Detection Circuit for details.

2.5 Motor Current Detection Circuit



JP701, JP702, JP703 Setting

JP	3 shunt *	1 shunt
701	Short	Open
702	Short	Open
703	Open	Short

* Default setting

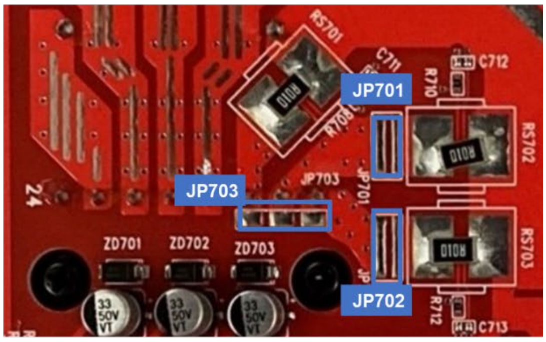


Figure 2-5 Motor Current Detection Circuit (3 shunt or 1 shunt)

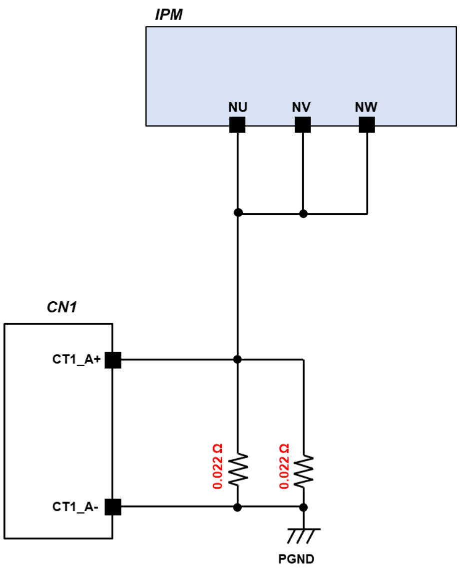


Figure 2-6 Motor Current Detection Circuit (1 shunt)

Figure 2-5 and Figure 2-6 are a schematic diagram of the Motor current detection circuit.

The Nu-KE-MTR_HV001 has Motor current detection circuit to measure the U, V, and W phase currents by the shunt resistor.

The voltage drop caused by the current flowing through the shunt resistor is amplified by the operational amplifier that built into the microcontroller and converted to digital value by A/D converter.
By setting JP701, JP702 and JP703, 1 shunt or 3 shunt current detection method can be switched.

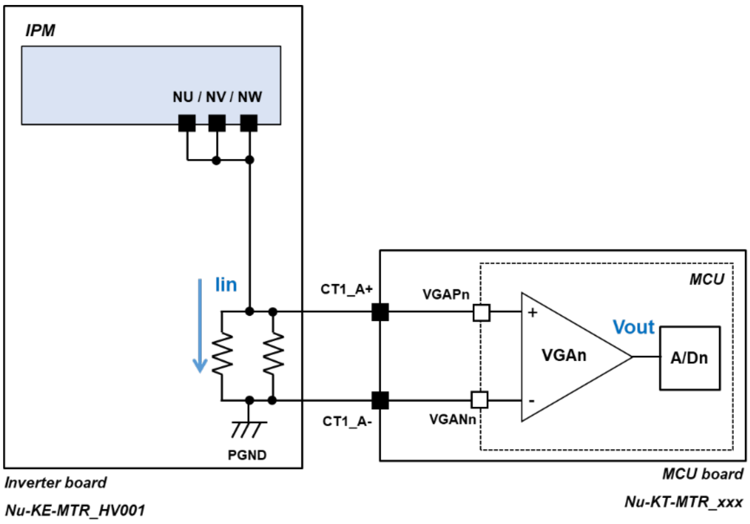


Figure 2-7 Motor Current Detection Circuit

Figure 2-7 is details of the Motor current detection circuit.
The configuration of 1 shunt current detection method is shown, but the configuration of 3 shunt current detection method is the same.

The relationship between the phase current (Iin) flowing through the shunt resistor and the voltage (Vout) input to the A/D converter is given by Equation (1).

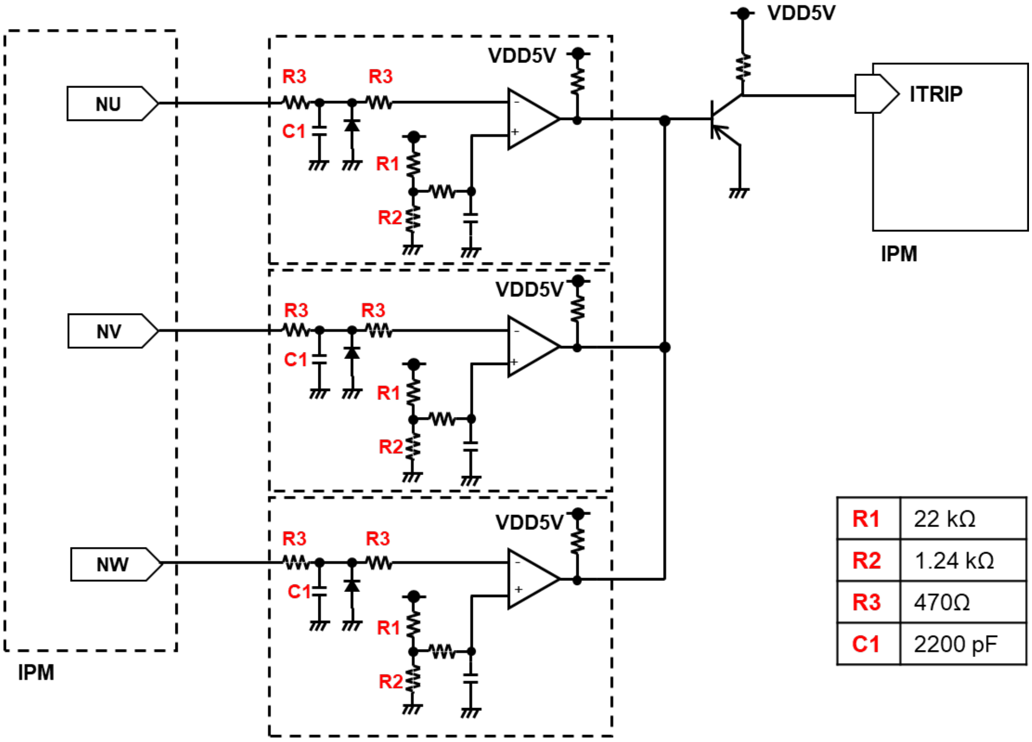
$$\text{Vout [V]} = \text{Iin [A]} \times \text{Rs } [\Omega] \times \text{VGA\_Gain} + \text{VGA\_VREF} \qquad (1)$$

■The parameters at default

Parameter	Description	Value
VGA_Gain	VGA output gain	10 times
VGA_VREF	VGA output reference voltage	2.5 V
Rs	Shunt resistor	0.01 Ω

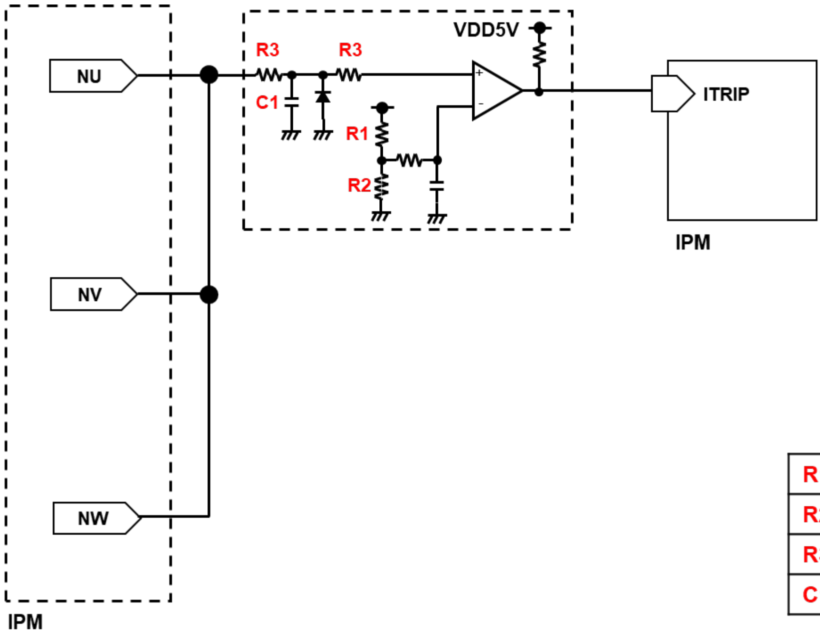
*The VGA output reference voltage and VGA output gain are set by software.

2.6 Overcurrent Detection Circuit



R1	22 kΩ
R2	1.24 kΩ
R3	470Ω
C1	2200 pF

Figure 2-8 Overcurrent Detection Circuit (3 shunt)



R1	18 kΩ
R2	1.15 kΩ
R3	470Ω
C1	2200 pF

Figure 2-9 Overcurrent Detection Circuit (1 shunt)

Figure 2-8 and Figure 2-9 are a schematic diagram of the overcurrent detection circuit.

The overcurrent detection circuit detects overcurrent event from the shunt current of each of the U, V, and W phases. When the current flowing through the U, V, and W phases exceeds the threshold value in any one, it is judged to be overcurrent event.

The overcurrent detection circuit sets the threshold value with the resistor voltage divider of resistors R1 and R2. By default, Nu-KE-MTR_HV001 implements resistors R1 and R2 to set the detection threshold at about 26.7 A.

When the overcurrent event occured, High level is input to the ITRIP pin of the gate driver IC, the output of the MOSFET is turned off instantly, and the EMG_2, EMG_2 (Active-Low) signal will be generated and input to the microcontroller, so that the board and the motor can be protected.

Please adjust the resistors R1 and R2 and set the detection thresholds according to the use environment. The detection threshold is given by Equation (2).

The detection threshold [A] = 5 [V] × R2 [Ω] / (R1 [Ω] + R2 [Ω]) / shunt resistor [Ω] (2)

■The detection threshold for the overcurrent detection at default.

5 [V] × 1.24 [kΩ] / (22 [kΩ] + 1.24 [kΩ]) / 0.01 [Ω] = 26.7 [A]

2.7 Power Factor Correction (PFC)

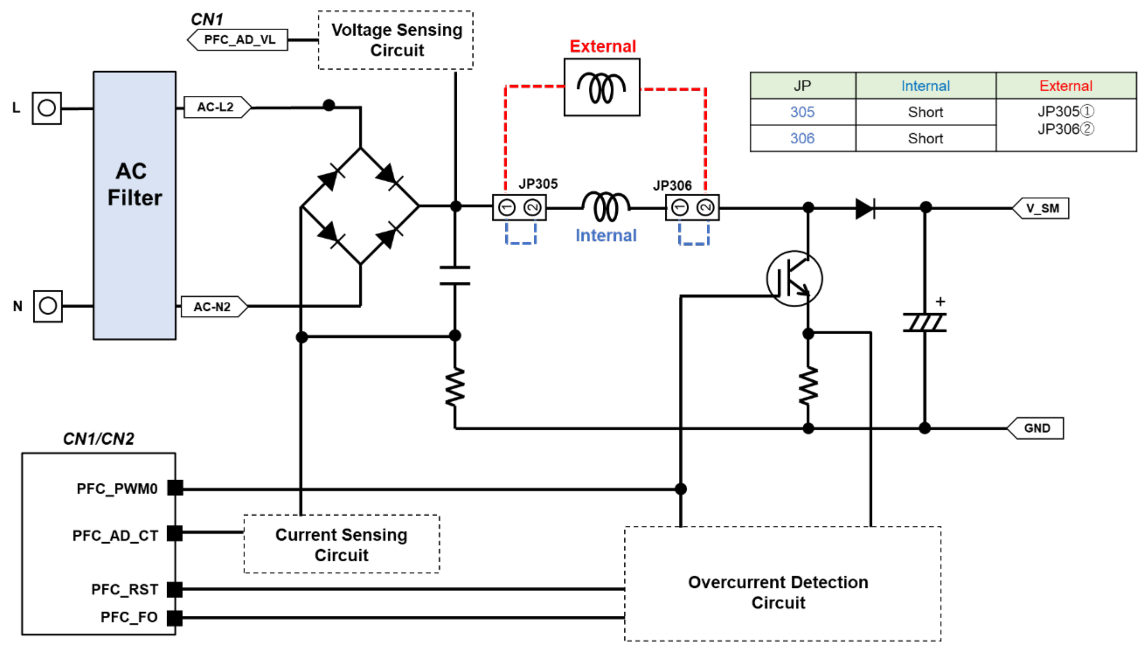


Figure 2-10 Power Factor Correction (PFC)

Figure 2-10 is a schematic diagram of the Power Factor Correction(PFC) circuit.

The Nu-KE-MTR_HV001 is equipped with a switching PFC circuit that improves the power factor by inserting a boost chopper circuit between the diode bridge and the load, controlling the current with a switch, and matching the phase with the input voltage.

The PFC control method is controlled by CCM (Continuous Conduction Mode), which continuously conducts current to the switching reactor.

The switching reactor is mounted on the board, but JP305 and 306 allow the use of external parts.

PFC has a current sensing circuit that measures the current of shunt resistor.

Please refer to 2.8 PFC Current sensing Circuit for details.

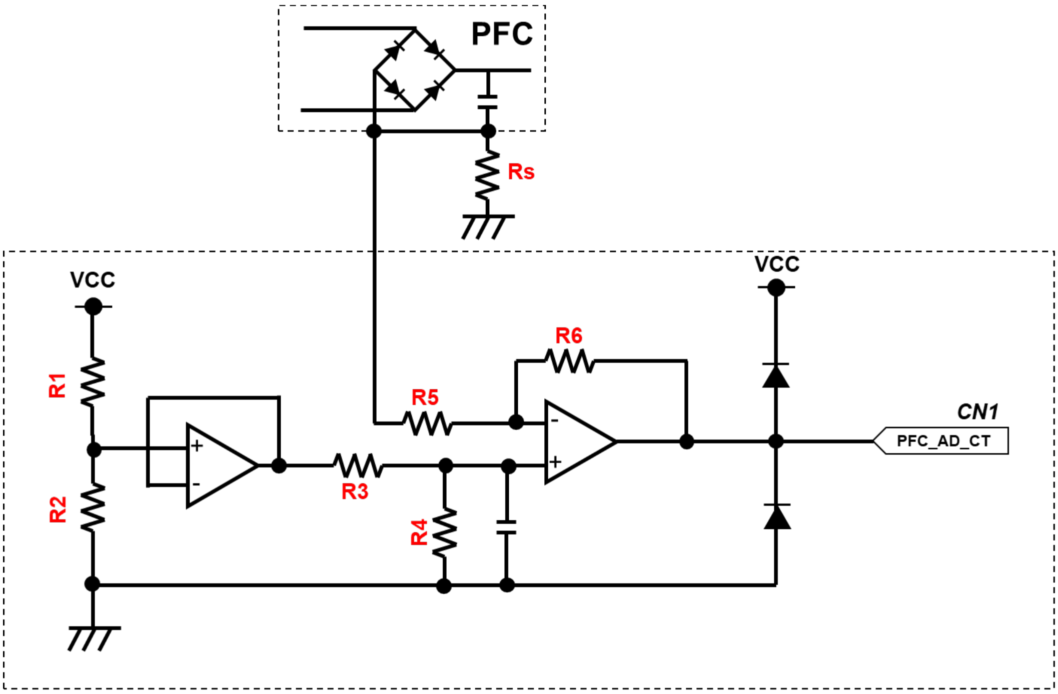
PFC has a overcurrent detection circuit that detects the overcurrent event from shunt current.

Please refer to 2.9 PFC Overcurrent Detection Circuit for details.

PFC has a voltage sensing circuit.

Please refer to 2.10 PFC Voltage sensing Circuit for details.

2.8 PFC Current Sensing Circuit



R1	9.1 kΩ
R2	1 kΩ
R3	6.8 kΩ
R4	1 kΩ
R5	1 kΩ
R6	6.8 kΩ
Rs	0.015 Ω

Figure 2-11 PFC Current Sensing Circuit

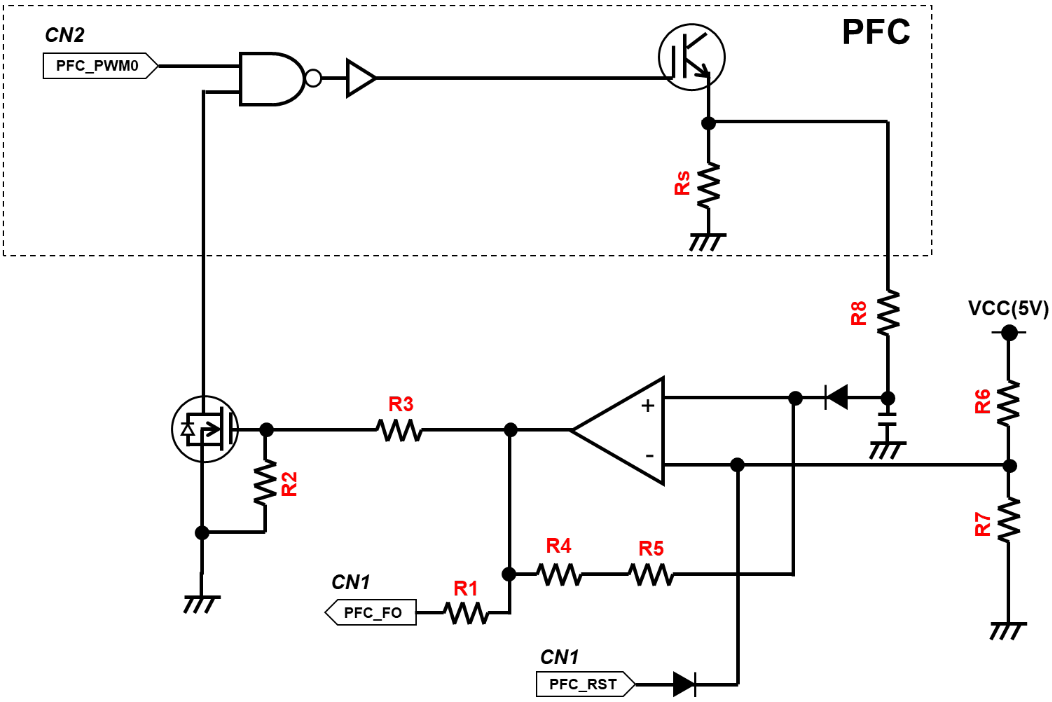
Figure 2-11 is a schematic diagram of the PFC current sensing circuit.

The Nu-KE-MTR_HV001 has PFC current sensing circuit to measure the current by the shunt resistor. The voltage drop caused by the current flowing through the shunt resistor is amplified by the operational amplifier that built into the microcontroller and converted to digital value by A/D converter.

The relationship between the phase current (I_{sh}) flowing through the shunt resistor and the voltage (Vout) input to the A/D converter is given by Equation (3).

$$
\begin{aligned}
Vout\ [V] &= V^{+} + (If \times R6\ ) \\
&= V^{+} + (\ (V^{+} - V_{sh})/R5 \times R6\ ) \\
&= (5\times R2/(R1+R2)\ ) + \{\ 5\times R2/(R1+R2) - (-I_{sh} * Rs)\ \}/R5 \times R6 \qquad (3)
\end{aligned}
$$

2.9 PFC Overcurrent Detection Circuit



R1	100 Ω
R2	22 kΩ
R3	330 Ω
R4	82 kΩ
R5	100 kΩ
R6	15 kΩ
R7	1 kΩ
R8	2 kΩ
Rs	0.02 Ω

Figure 2-12 PFC Overcurrent Detection Circuit

Figure 2-12 is a schematic diagram of the PFC overcurrent detection circuit.

The overcurrent detection circuit detects overcurrent event from the shunt.
The IGBT is protected by overcurrent detection.

The overcurrent detection circuit sets the threshold value with the resistor voltage divider of resistors R6 and R7. By default, Nu-KE-MTR_HV001 implements resistors R6 and R7 to set the detection threshold at about 30.625 A.

When an overcurrent event occurs, a Hi level FO signal is input to the microcomputer and the IGBT gate signal goes Low at the same time.

Please set the overcurrent detection threshold by changing the voltage dividing resistance according to the usage environment.

The detection threshold is given by Equation (4).

$V_{OCP\_th} = 5 \times R7/(R6+R7) + Vf$ (4)

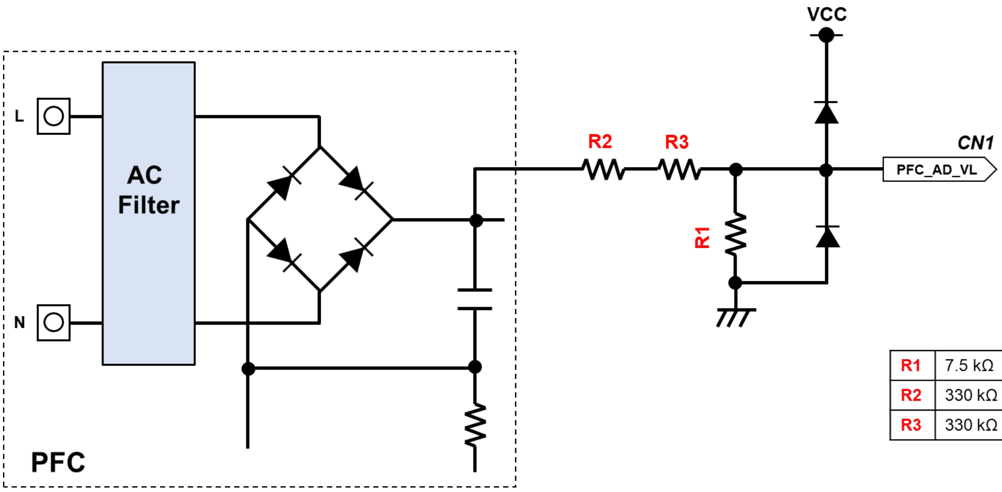
$I_{OCP} = V_{OCP\_th} / Rs$

■The detection threshold for the overcurrent detection at default.

$I_{OCP} = 0.6125 / 0.02$

$= 30.625[A]$

2.10 PFC Voltage Sensing Circuit



R1	7.5 kΩ
R2	330 kΩ
R3	330 kΩ

Figure 2-13 PFC Voltage Sensing Circuit

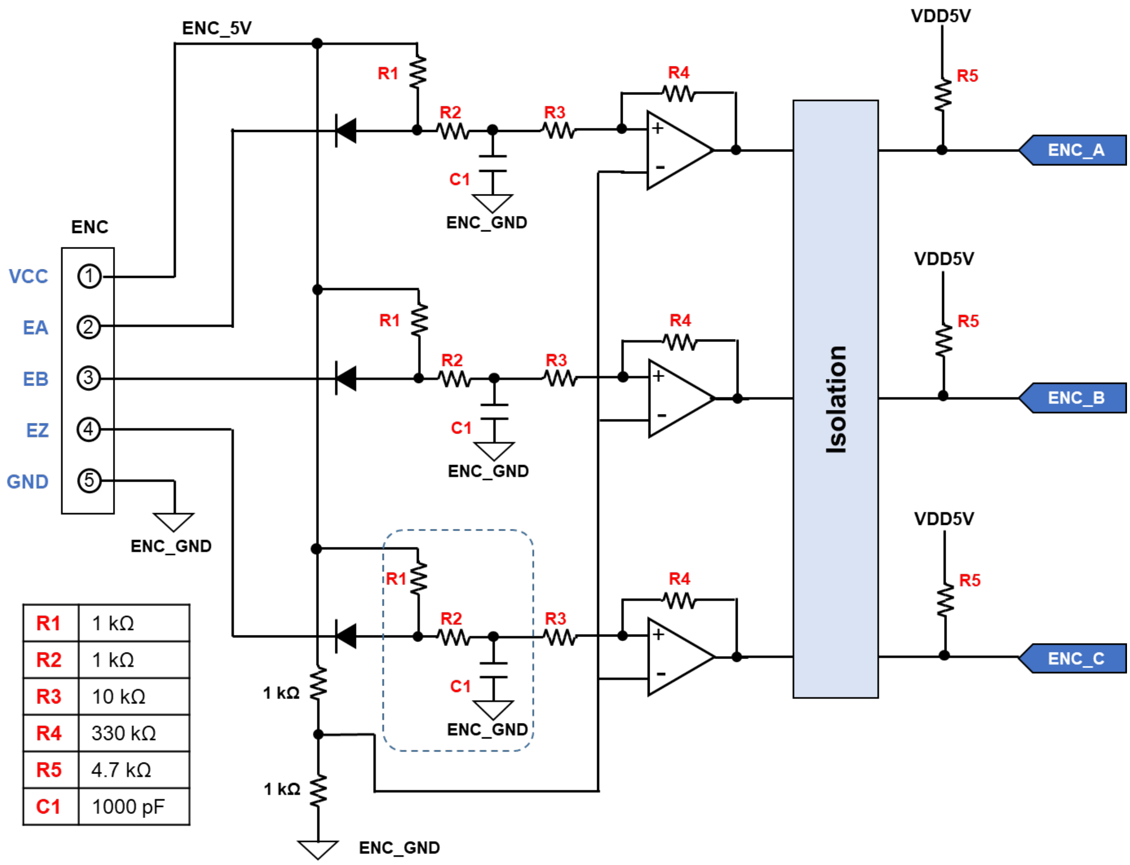
Figure 2-13 is a schematic diagram of the PFC voltage sensing circuit.

The voltage sensing circuit detects the AC voltage of the PFC.

The relationship between the voltage(Vin) and the input to the A/D converter(Vout) is given by Equation (5).

$$Vout\ [V] = Vin \times R1/(R1 + R2 + R3) \qquad (5)$$

2.11 Encoder



R1	1 kΩ
R2	1 kΩ
R3	10 kΩ
R4	330 kΩ
R5	4.7 kΩ
C1	1000 pF

Figure 2-14 Encoder Circuit

Figure 2-14 is a schematic diagram of the encoder circuit.

The Nu-KE-MTR_HV001 has connector for connecting to an encoder.
The encoder signal is isolated by a photo coupler. In addition, each signal has a filter inserted.
The time constant CR of the filter is given by Equation (6).

$$\text{The time constant CR [sec]} = (\text{R1} + \text{R2}) \times \text{C1} \qquad (6)$$

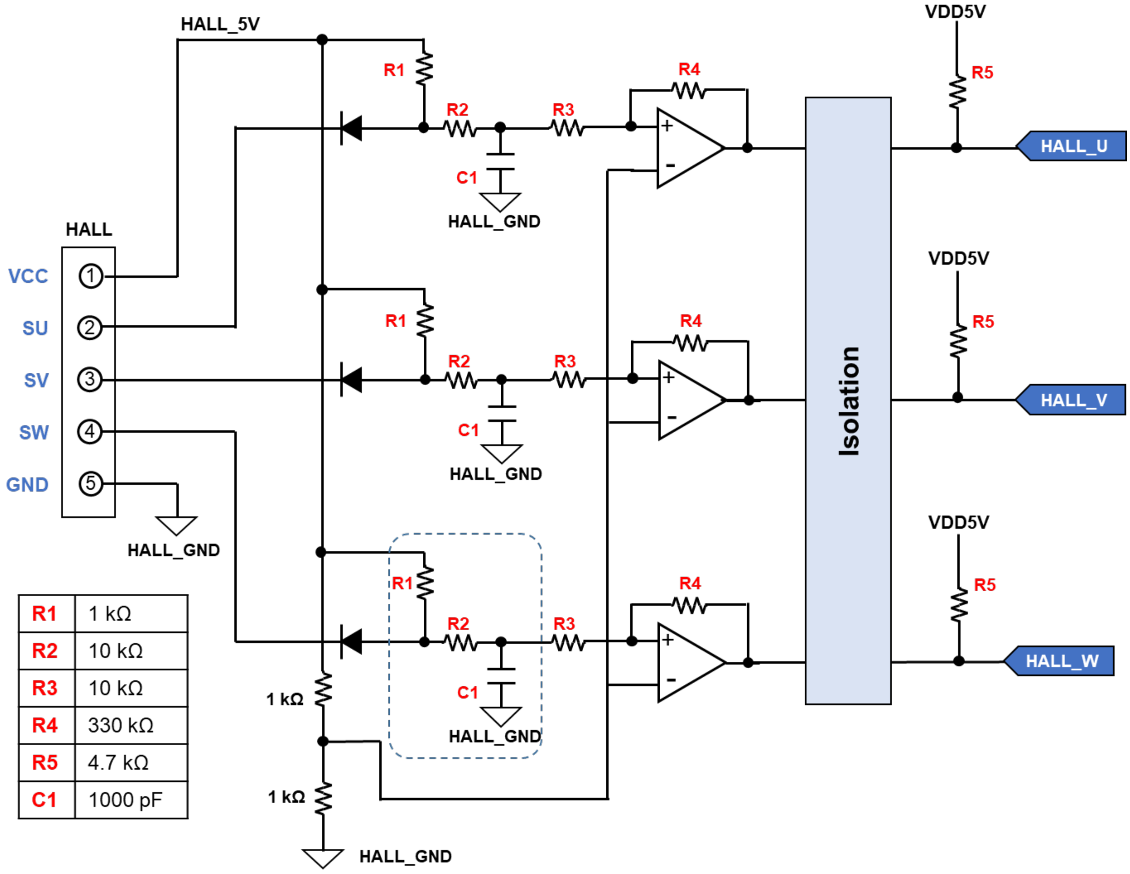
■The time constant CR of the filter at default.

The time constant CR = (1 [kΩ] + 1 [kΩ]) × 1000 [pF] = 2 [μsec]

Please adjust the time constant of the filter according to the encoder specifications to be used.

For the filter on the MCU board side, please refer to the circuit diagram in the user manual of the the inverter control MCU board Nu-KT-MTR_xxx (xxx:MCU parts number).

2.12 Hall sensor



R1	1 kΩ
R2	10 kΩ
R3	10 kΩ
R4	330 kΩ
R5	4.7 kΩ
C1	1000 pF

Figure 2-15 Hall sensor Circuit

Figure 2-15 is a schematic diagram of the Hall sensor circuit.

The Nu-KE-MTR_HV001 has connectors for connecting to a Hall sensor. The Hall sensor signal is isolated by a photo coupler. In addition, each signal has a filter inserted.
The time constant CR of the filter is given by Equation (7).

$$\text{The time constant CR [sec]} = (R1 + R2) \times C1 \qquad (7)$$

■The time constant CR of the filter at default

The time constant CR = (1 [kΩ] + 10 [kΩ]) × 1000 [pF] = 11 [μsec]

Please adjust the time constant of the filter according to the Hall sensor specifications to be used.
When using, see also 2.11 Jumper.

For the filter on the MCU board side, please refer to the circuit diagram in the user manual of the the inverter control MCU board Nu-KT-MTR_xxx (xxx:MCU parts number).

2.13 DIP Switch

The Nu-KE-MTR_HV001 has a DIP switch. You can make use of the DIP switch as you like.

DIP Switch	Connector	Description
SW0	CN2.21	ON:Hi input , OFF:Lo input
SW1	CN2.22	ON:Hi input , OFF:Lo input
SW2	CN2.23	ON:Hi input , OFF:Lo input
SW3	CN2.24	ON:Hi input , OFF:Lo input

Table 2-1 DIP Switch

2.14 LEDs

The Nu-KE-MTR_HV001 has one LED for Power indication and two user-specified LEDs .

LED	Connector	Description
LED401	-	LED for Power
LED21	CN2.19	Low Output : ON / High Output : OFF
LED22	CN2.20	Low Output : ON / High Output : OFF

Table 2-2 LED setting

2.15 MCU board Connectors

Table 2-3 shows the MCU board connectors.

Connector	Description
CN1, CN2	Mount the MCU board.

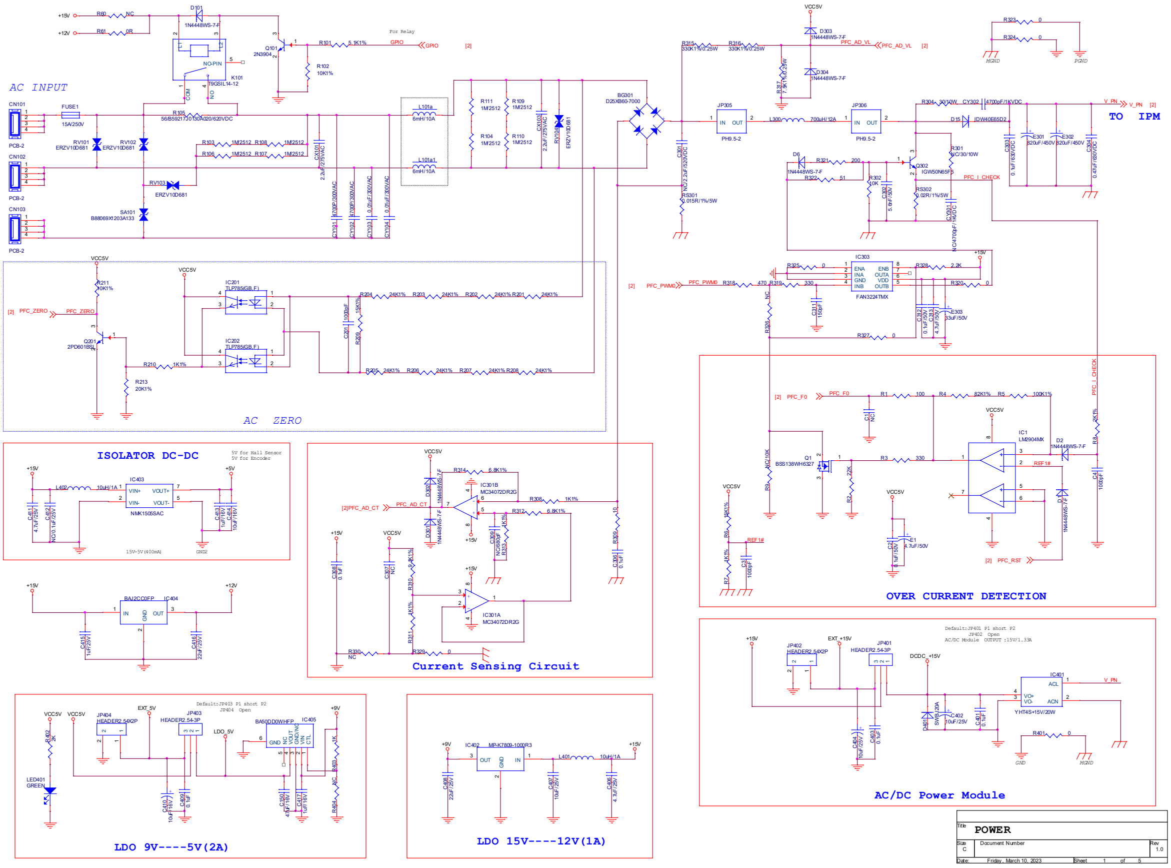
Table 2-3 Inverter board Connectors

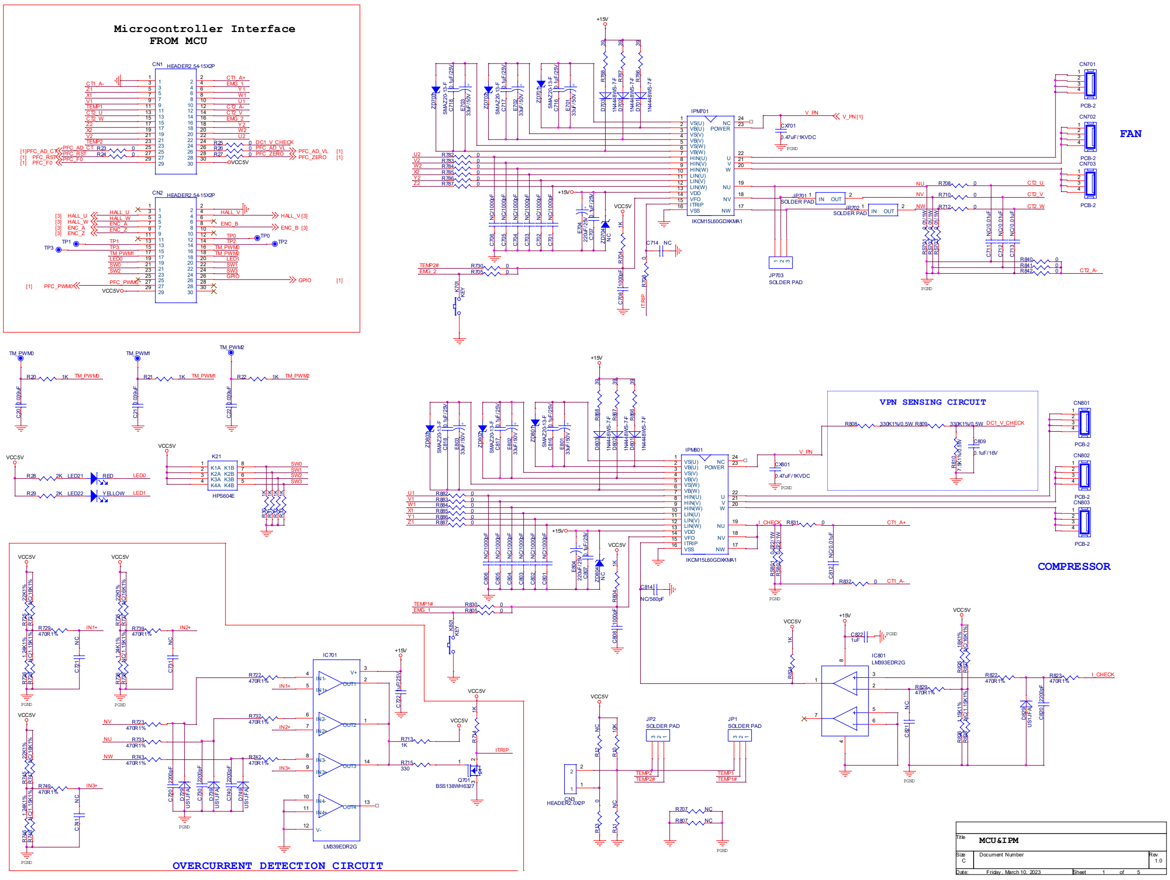
Please refer to the user manual of the the inverter control MCU board Nu-KT-MTR_xxx (xxx:MCU parts number).

3. Nu-KE-MTR_HV001 SCHEMATICS

3.1 Nu-KE-MTR_HV001

Figure 3-1 shows the Nu-KE-MTR_HV001 schematic.




Microcontroller Interface
FROM MCU
FAN
VPN SENSING CIRCUIT
COMPRESSOR
OVERCURRENT DETECTION CIRCUIT
MCU&IPM

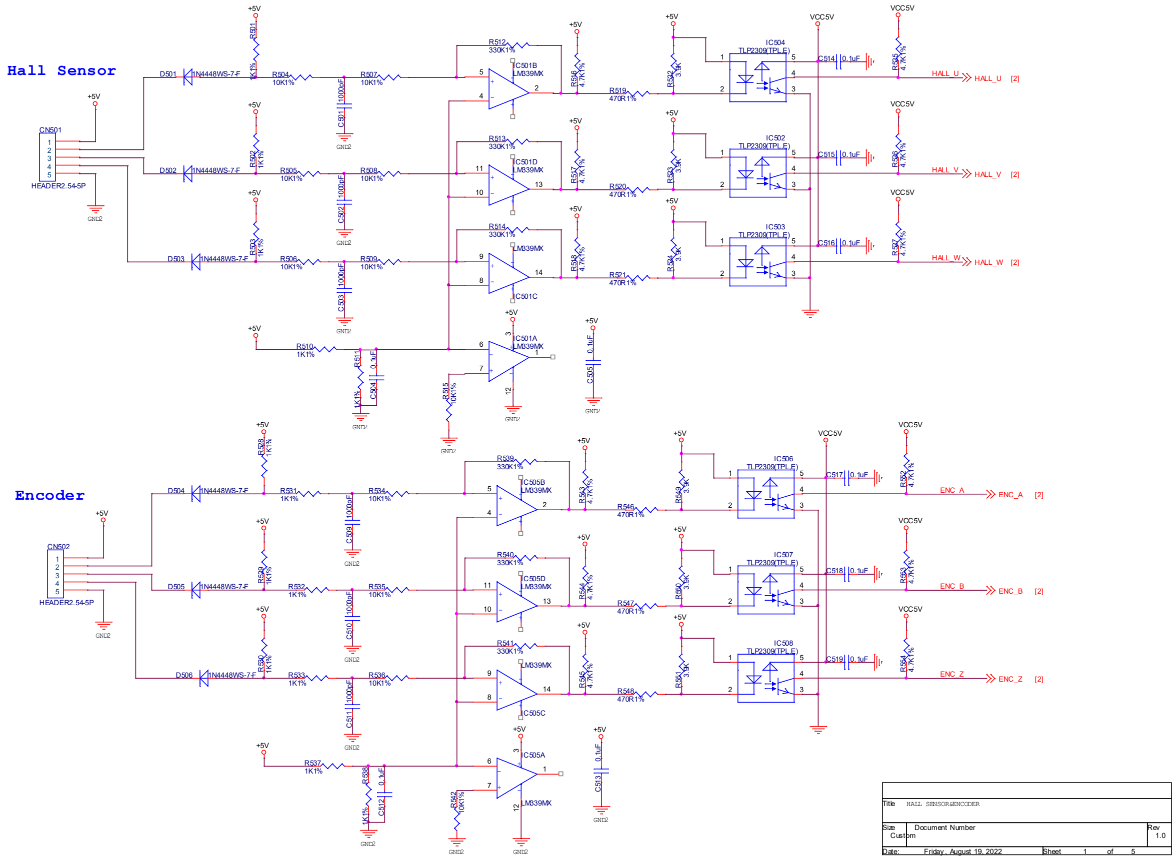


Figure 3-1 Nu-KE-MTR_HV001 Schematic

3.2 PCB Component Placement

Figure 3-2 and Figure 3-3 show the top and bottom PCB component placement of Nu-KE-MTR_HV001.

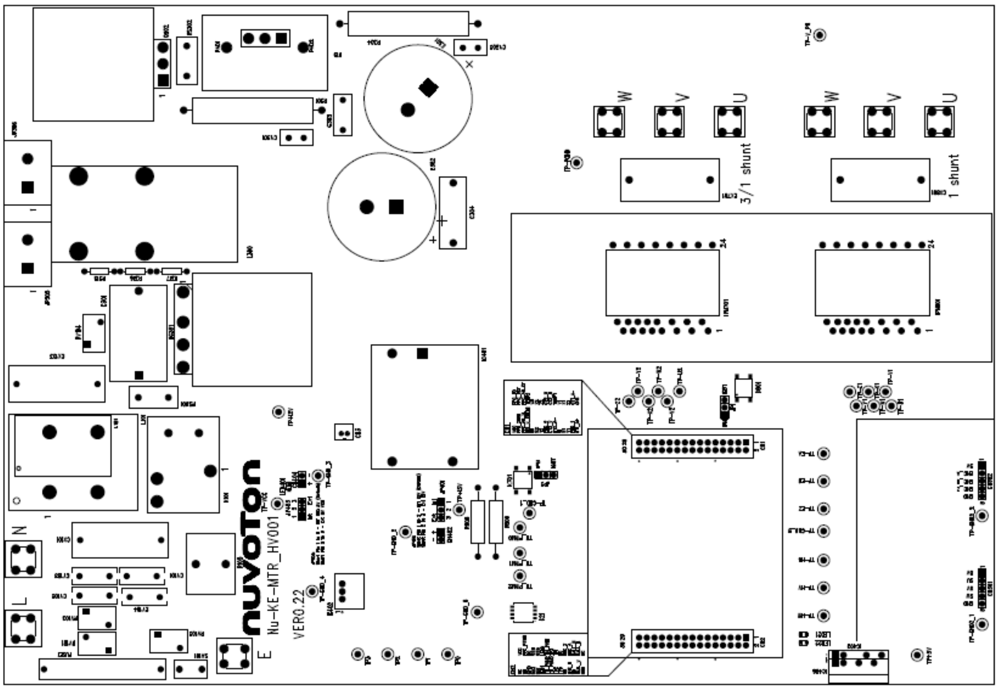


Figure 3-2 Top Placement

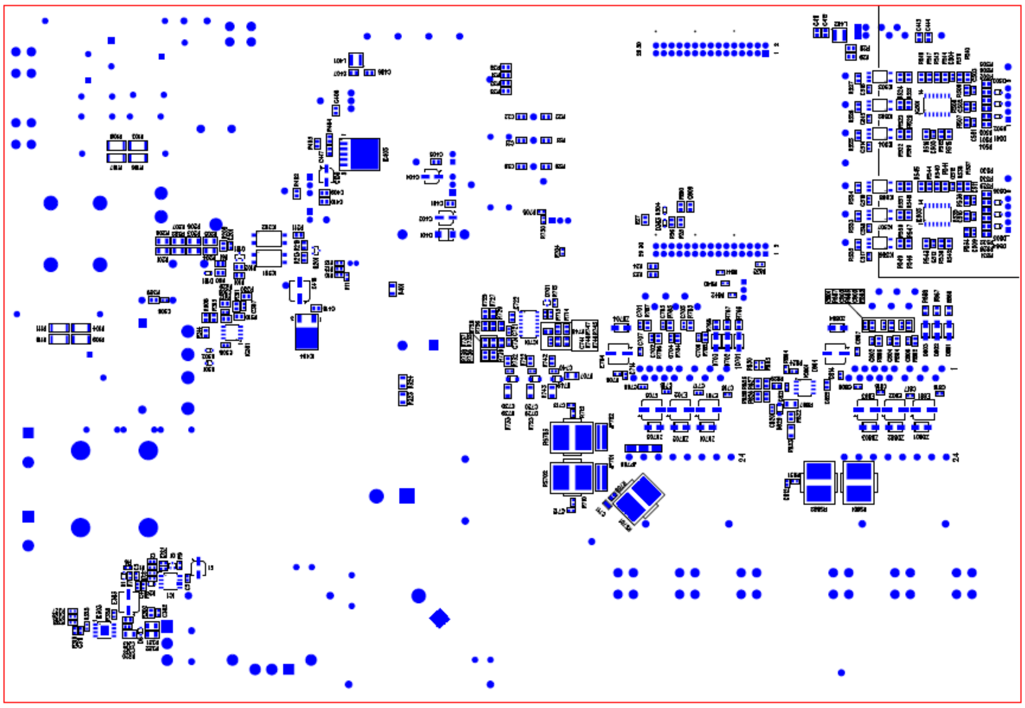


Figure 3-3 Bottom Placement

4. REVISION HISTORY

Date	Revision	Description
September 1, 2022	1.00	· Initial version
March 16, 2023	1.01	· 1.OVERVIEW Fixed Rated output power value · Corrected description in 2.6 Overcurrent Detection Circuit. · Corrected description in 2.9 PFC Overcurrent Detection Circuit. · Corrected description in 3.1 Nu-KE-MTR_HV001. · Corrected description in 3.2 PCB Component Placement .
April 24, 2023	1.02	· Corrected description in 1.OVERVIEW. · Corrected description in 2.8 PFC Current Sensing Circuit. · Corrected description in 2.9 PFC Overcurrent Detection Circuit. · Corrected description in 2.10 PFC Voltage Sensing Circuit. · Corrected description in 2.11 Encoder. · Corrected description in 2.12 Hall sensor.

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