Analog Modular Extension for Motor Management Relay

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Abstract**—**Motor Management Relay enhances VFD protection and provides redundant backup control for VFD normal operation, malfunction, soft start bypass, maintenance, or replacement. The primary aim of Motor Management Relay is to provide protection in various aspects using expansion units. Analog output modules send out a varying current or voltage signal. By means of the analog module,the main unit can be optionally expanded by analog inputs and outputs (4 mA to 20 mA). As a result, it is possible to measure and monitor any process variable which can be mapped on to a 4mA - 20-mA signal for a 200 load for a voltage range of 0-10V. However, in the following paper, we can allow the user to obtain the current output at a wider range of 0-20V across a 1k load

Keywords—*VFD, expansion units, analog module, load current*

I. INTRODUCTION

The motor protection relay has been designed to provide comprehensive, intelligent motor protection. The main unit is a self-contained, fully functional unit housing the main processor, input/output board, current and voltage board and a communication board in a single module enclosure. The motor protection relay provides all basic current, voltage and frequency protection. It also provides motor-specific protection like locked rotor, 0number of starts, excessive start time, phase reversal and phase loss. The relay also consists of expansion unit, where the digital input/output capacity can be increased and various analog modules for different types of protection like earth fault, power fault protection can be employed. The mode of each output can be individually selected between current or voltage output. Shielded cable for the analog outputs is recommended. The terminals of the HF shield should be used, when connecting the shield to the ground on both sides of the cable is not possible. On one side of the cable the shield has to be directly connected to ground. In case of the use of unshielded twisted pair cables, the length must not exceed 10 m. All analog outputs have a common potential. Each output has an own common terminal.

The analog module allows you to expand basic unit pro V by one analog output. The corresponding function block allows every analog value (2 bytes / 1 word) in SIMOCODE pro to be output as a 0/4 to 20 mA signal to a connected pointer instrument, for example. If the function block is activated via the "Assigned analog output value" plug using any integer value between 0 and 65,535, an equivalent analog signal of 0 to 20 mA or 4 to 20 mA will be sent to the output terminals of the analog module. Now this is obtained for a 200k load,but by modifying the circuit diagram and using a boost converter, we can obtain wider range of voltage for just 1k load.

II. PROPOSED SYSTEM

The Motor Management relay in question has the analog inputs from 4mA to 20mA. Analog inputs can be used for generating alarms to the control center, or tripping the motor and shutting down the machine prior to failure. The inputs are sampled every second, and the level of the analog input is also available over the serial communication port. The relay is used to monitor the mechanical conditions of either the main machine, or any associated ancillary equipment, as part of the process. There might be occasions where a mechanical failure of the associated equipment implies the immediate removal from service of the main machine.

For an input of 4mA-20mA, usually after accounting for the voltage drop, output range for the user is between 0-10V, for a load of 200k. But in the proposed system, the circuitry is modified and a boost converter is used to obtain a current of 4-20mA across 1K load with a variable voltage range of 0-20V

III. SYSTEM DESIGN

The motor protection relay consists of Main unit, current module unit, expansion unit and the operator panel or OLED unit.

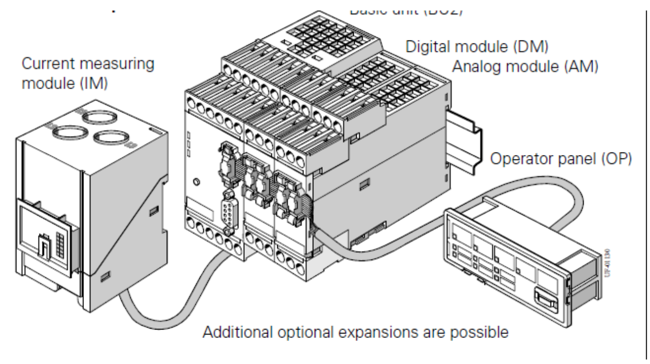

Fig.1: Motor Management Relay Structure

a. THE MAIN UNIT

This is self-contained and fully functional unit housing the main processor, input/output board, current & voltage board and a communication board in a single module enclosure. The main unit is also equipped with Bi/Tri colour LED for status indication. There is also reset push button available for local trip reset.

b. CURRENT MODULE UNIT

It comes in two sizes and is suitable for use from 0.375kW. The CM is a pass-through type and hence there is no need of physical termination of power wire and CT shorting while removing the motor protection relay.

c. OLED DISPLAY UNIT

The OLED Display Unit is a detachable optional unit provided with relay for display of all metering, protection and fault data. The OLED display unit is provided with mini-USB port on its front facia to enable local configuration through laptop using the relay.

d. EXPANSION UNIT

The expansion units consists of analog modules which allow the main unit to expand. The analog output modules enable the user to provide certain range of current/ voltage outputs. They also employ various other protections required in the motor protection relay.

Fig.2 Motherboard of Expansion Unit

e. BOOST CONVERTER

Switched mode supplies can be used for many purposes including DC to DC converters. Often, although a DC supply, such as a battery may be available, its available voltage is not suitable for the system being supplied. For example, the motors used in driving electric automobiles require much higher voltages, in the region of 500V, than could be supplied by a battery alone. Even if banks of batteries were used, the extra weight and space taken up would be too great to be practical. The answer to this problem is to use fewer batteries and to boost the available DC voltage to the required level by using a boost converter. Another problem with batteries, large or small, is that their output voltage varies as the available charge is used up, and at some point the battery voltage becomes too low to power the circuit being supplied. However, if this low output level can be boosted back up to a useful level again, by using a boost converter, the life of the battery can be extended.

IV. WORKING OF THE SYSTEM

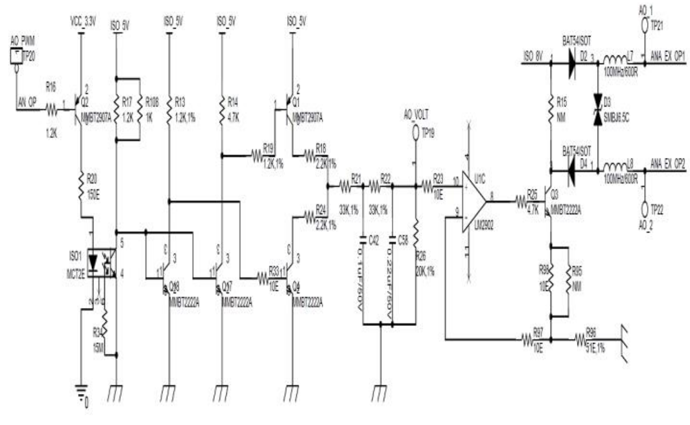

Fig 3. Analog Output circuit diagram for 200K load

Given above is the Analog Output circuit diagram for a 200k load.

1. Charge across capacitor C58 for **100%** duty cycle can be calculated as,
   Vfiltered = 1.0 * 5v * 20k / (2.2k + 33k + 33k + 20k)
   = 1.0 * 5v * 0.226757
   = 1.13379 Volt
2. For **50%** duty cycle,
   Vfiltered = 0.5 * 5v * 0.226757
   = 0.56689 Volt
3. For **0%** duty cycle,
   Vfiltered = 0.0 * 5v * 0.226757
   = 0.0 Volt
4. For **90%** duty cycle,
   Vfiltered = 0.9 * 5v * 0.226757
   = 1.0204 Volt

Analog O/P is generated with help of 10 KHz PWM signal. In first stage PWM signal is converted to DC voltage signal and in second stage voltage to current conversion is done with help of constant current source.

a. First stage (PWM to voltage conversion):
Microcontroller drives Opto-coupler using transistor.

1. At the collector of Opto-coupler, Isolated PWM signals will appear

2. This isolated PWM signals will drive a half-bridge, which will letter charges the capacitor according to duty cycle of the signals.
3. Two stage cascade passive filter helps in order to filter PWM signals with better cut-off slope.
4. Thus the voltages across capacitor C58 are in linearly proportion with duty cycle of PWM signal.
5. Charge across capacitor C58 for **100%** duty cycle can be calculated as,

Vfiltered = 1.0 * 5v * 20k / (2.2k + 33k + 33k + 20k)
= 1.0 * 5v * 0.226757
= 1.13379 Volt

For **50%** duty cycle,
Vfiltered = 0.5 * 5v * 0.226757
= 0.56689 Volt

For **0%** duty cycle,
Vfiltered = 0.0 * 5v * 0.226757
= 0.0 Volt

For **90%** duty cycle,
Vfiltered = 0.9 * 5v * 0.226757
= 1.0204 Volt

b. Second stage (Constant current source):

1. Op-amp U1C, Transistor Q3 & feedback resistor R96 creates constant current source.

2. Calculation of feedback resistor:
Let, **20mA** required at **90%** of duty cycle.
Now C58 holds 1.0204 voltages for 90% PWM duty cycle.
R feedback = V / I
= 1.0204v / 20mA
= **51.02 Ohm**

3. So, 51E resister is selected as feedback resistor.
4. Now according to this, Duty cycle required for **4mA** output,
Vfiltered = I * R
= 4mA * 51E
= 0.204 Volt

Duty cycle = 100 * Vfiltered / (VCC * 20k / (2.2k + 33k + 33k + 20k))
= 100 * 0.204 / (5v * 0.226757)
= 100 * 0.204 / 1.133785
= **17.99%**

5. Maximum current @ **100%** duty cycle
I Out = Vfiltered / R
= 1.13379 / 51E
= 0.02223 A
= **22.23 mA**

V. OBSERVATIONS AND READINGS

The changes and the observations made after replacing the circuit with 1K load are listed as follows:

1. Pin No. 2 & 4 of opto coupler ISO14N35 are shorted.
2. The 3.3V from the motherboard connector designed for the 0-10 V range is boosted to 24V using a boost converter.
3. When 24V is directly given instead of ISO 8V, the voltage across 1K resistor is 19V due to voltage drop and the current is 19mA.
4. Thus, Diode D4 is removed and 51E resistor is replaced by 39E resistor. Now the current increases to 21.22mA for a wider voltage range.

The output observed at different duty cycles across the load is as follows:

1. At 10%, Max voltage= 4.20V
   Min voltage=200mV
2. At 50% Max voltage = 10V
   Min voltage = 2.40V
3. At 90% Max voltage= 23.6V
   Min voltage = 22.8V

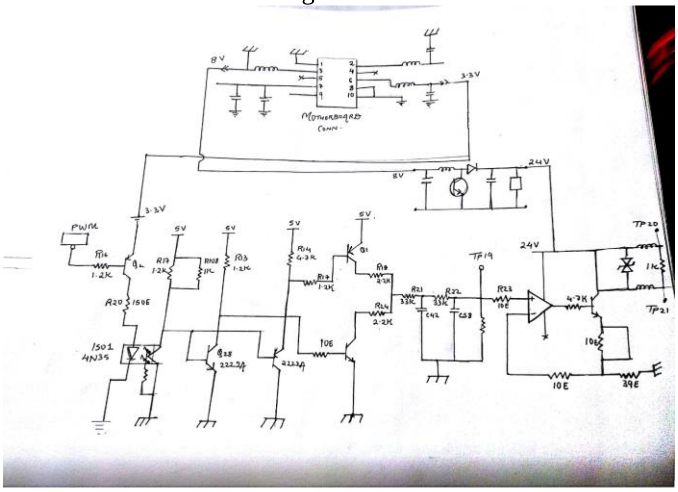

Fig 4.Analog Output Circuit Diagram for 1K load

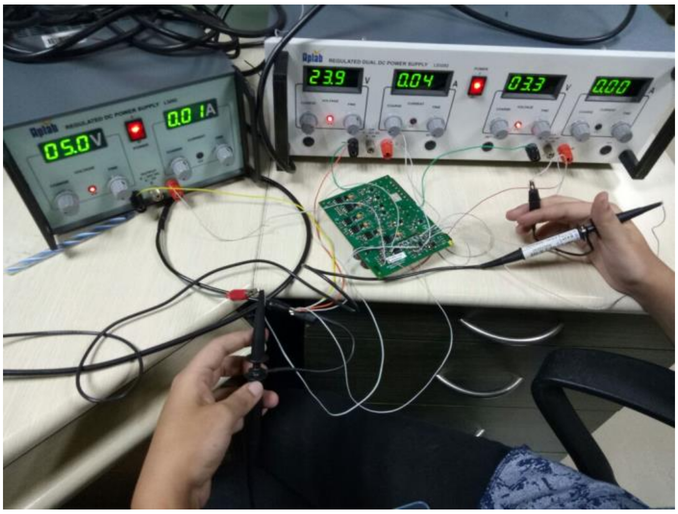

Fig 5. Setup for the experiment

VI. CONCLUSION

Thus we can infer from the above experiment conducted that a 4-20 mA current can obtained across a 1K load for a voltage range of 4-20V as well. This helps to connect four 200k load expansion units, each performing a different protection function to the same motor. This provides the ultimate protection for a motor of any size without causing any overload.

VII. FUTURE SCOPE

This project can be further enhanced by providing load management for two or more motors together. This would require multiple expansion units functions to be combined together and thus much larger load management capacity.

VIII. REFERENCES

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