LINEAR REGULATOR FOR THE ELECTRIC MOTOR OF AN AIR COMPRESSOR FOR MAINTAINING A CONSTANT PRESSURE INSIDE THE VESSEL

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Abstract:
Because the electric motor of the compressor is a variable speed motor, it is necessary to attach a linear regulator in order to maintain a constant pressure inside the compressor's vessel. The paper present the circuit lay-out of a linear regulator used to maintain a constant pressure inside the compressor's vessel.

Keywords: linear regulator, compressor, vessel, electric motor

1. INTRODUCTION

The vessel used is a storage vessel for compressed air used in various pneumatic installations which are equipped with air compressors with maximum work pressure of 0.12 MPa.

The horizontal vessel has a steel cylinder, longitudinally welded, with interior diameter of 305 mm and thickness of 4 mm. At each end, the cylinder has two welded ellipsoidal heads.

A $M\,24\times1.5\,\Phi12$ nozzle on the cylinder is used for air inlet and a $M\,22\times1.5\,\Phi14$ nozzle on one of the heads is used for air outlet. The vessel has a $\Phi120/\Phi180$ welded flange mounted on the upper side of the cylinder, together with a nozzle for air outlet towards to control equipments: manometer, safety valve. A nozzle for purging the air is mounted in the lower side of the vessel.

The vessel has the following technical characteristics:

- Vessel capacity: 140 l;
- Maximum admissible work pressure: 1.2 MPa;
- Maximum admissible work temperature: +200°C;
- Minimum admissible work temperature: -20°C;
- Work fluid: air;
- Hydraulic test pressure: 1.6 MPa.

The vessel is also the study object from an experimental installation for determination of strain and stress state in vessel's wall. The strain and stress state is determined in different points from the surface of the shell, for different internal pressure values. In order to have variable internal pressure values at different *t* time moments of the study, we choose a variable speed electric motor. From this reason it was necessary to realize an electronic circuit to control the electric motor and, therefore, the internal pressure.

The paper presents the circuit lay-out of a linear regulator.

2. THE BASIC LINEAR VOLTAGE REGULATOR

The linear regulator is the basic building block of nearly every power supply used in electronics. The IC linear regulator is so easy to use that it is virtually foolproof, and so inexpensive that it is usually one of the cheapest components in an electronic assembly.

This paper will present information of how the linear regulator works.

A linear regulator operates by using a voltage-controlled current source to force a fixed voltage to appear at the regulator output terminal (see Figure 1).

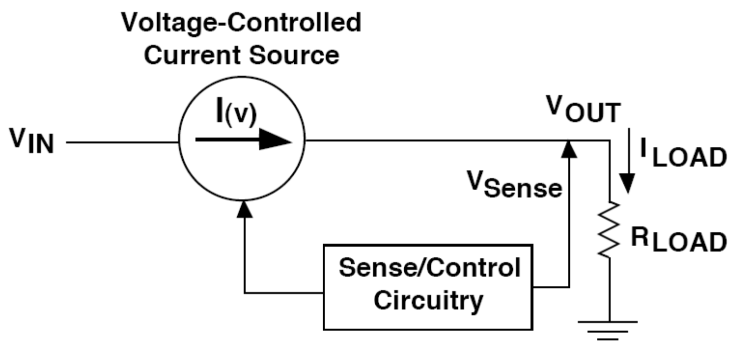

Figure 1 Linear regulator functional diagram

The control circuitry must monitor (sense) the output voltage, and adjust the current source (as required by the load) to hold the output voltage at the desired value. The design limit of the current source defines the maximum load current the regulator can source and still maintain regulation.

The output voltage is controlled using a feedback loop, which requires some type of compensation to assure loop stability. Most linear regulators have built-in compensation, and are completely stable without external components. Some regulators (like Low-Dropout types), do require some external capacitance connected from the output lead to ground to assure regulator stability. Another characteristic of **any** linear regulator is that it requires a finite amount of time to "correct" the output voltage after a change in load current demand. This "time lag" defines the characteristic called **transient response**, which is a measure of how fast the regulator returns to steady-state conditions after a load change.

3. CONTROL LOOP OPERATION

The operation of the control loop in a typical linear regulator will be detailed using the simplified schematic diagram in Figure 2 (the function of the control loop is similar in all of the linear regulator types).

The **pass device (Q1)** in this regulator is made up of an NPN Darlington driven by a PNP transistor (this topology is a Standard regulator, as detailed in the following section). The current flowing out the emitter of the pass transistor (which is also the load current IL) is controlled by Q2 and the voltage error amplifier. The current through the R1, R2 resistive divider is assumed to be negligible compared to the load current.

The feedback loop which controls the output voltage is obtained by using R1 and R2 to "sense" the output voltage, and applying this sensed voltage to the inverting input of the voltage error amplifier. The non-inverting input is tied to a reference voltage, which means the error amplifier will constantly adjust its output voltage (and the current through Q1) to force the voltages at its inputs to be equal.

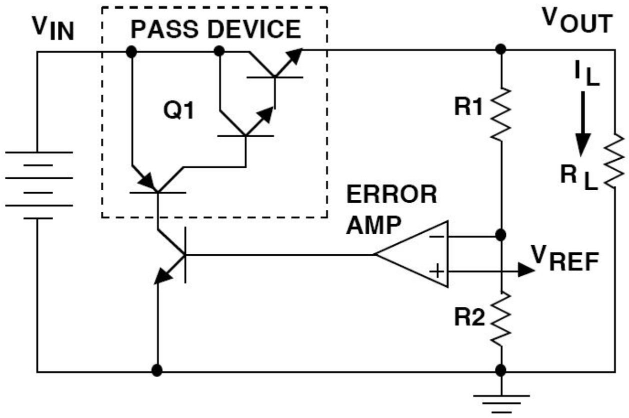

Figure 2 Diagram of a typical linear regulator

The feedback loop action continuously holds the regulated output at a fixed value which is a multiple of the reference voltage (as set by R1 and R2), regardless of changes in load current. It is important to note that a **sudden** increase or decrease in load current demand (a "step" change in load resistance) will cause the output voltage to change until the loop can correct and stabilize to the new level (this is called **transient response**). The output voltage change is sensed through R1 and R2 and appears as an "error signal" at the input of the error amplifier, causing it to correct the current through Q1.

4. THE STANDARD (NPN) REGULATOR

The first IC voltage regulators made used the NPN Darlington configuration for the pass device, and are designated as the **Standard** regulator (see Figure 3).

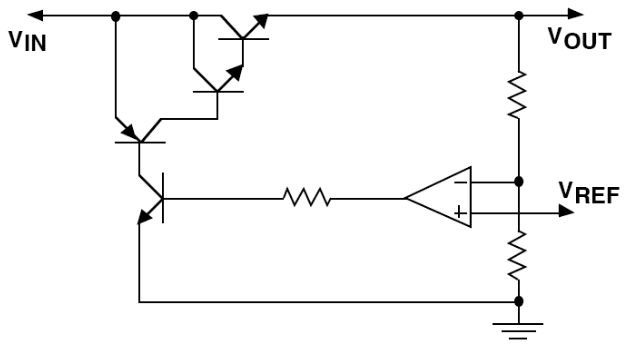

Figure 3 Standard (npn) regulator

An important consideration of the Standard regulator is that to maintain output regulation, the pass transistor requires a **minimum** voltage across it given by:

$$V_{D(MIN)} = 2 \cdot V_{BE} + V_{CE} \tag{1}$$

Allowing for the -55°C to +150°C temperature range, this minimum voltage requirement is usually set at about **2.5V to 3V** by the manufacturer to guarantee specified performance limits. The voltage where the output actually falls out of regulation (called the **dropout voltage**) will probably be somewhere between 1.5V and 2.2V for a Standard regulator (it is **dependent on both load current and temperature**). **The dropout voltage of the Standard regulator is the highest (worst)** of the three types.
The ground pin current of the Standard regulator is very low (an LM309 can supply 1A of load current with less than 10 mA of ground pin current). The reason for this is that the **base drive current to the pass transistor**

(which flows out the ground pin) is equal to the load current divided by the gain of the pass device. In the Standard regulator, the pass device is a network composed of one PNP and two NPN transistors, which means the total current gain is extremely high (>300). The result of using a pass device with such high current gain is that very little current is needed to drive the base of the pass transistor, which results in less ground pin current. **The ground pin current of the Standard regulator is the lowest (best)** of the three regulator types.

Reference

[1] Chester, S., *Linear and Switching Voltage Regulator Fundamentals*, National Semiconductor, 1999;
[2] *** *Linear & Switching Voltage Regulator Handbook*, SCILLC, 2002.