

SOME ASPECTS OF MICROCONTROLLERS APPLICATIONS IN SWITCHED MODE POWER SUPPLY FOR THE PULSE GENERATOR OF ELECTROEROSION MACHINES

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Abstract: This paper briefly presents evolution of the Power Supply for Pulse Generator and makes obvious some possibilities using of microcontrollers in Switched Mode Power Supply.

Keywords: Power Supply, microcontroller, analog control, digital control, communication modules

1. INTRODUCTION

The electrical voltage necessary for Electrostatic Discharge Machining (EDM) is applied between Object Tool (OT) and Object Processed (OP) by the Pulse Generator. The simplified diagram of typical pulse is shown in figure 1.

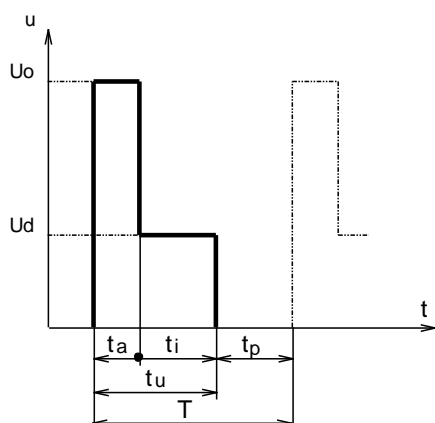


Fig.1. The typical diagram of voltage pulse.

- U_o is the breakdown voltage and his value is fixed by power supply.
- U_d is the voltage during the discharge, and it has a little fall and radiofrequency noise.

The Pulse Generator needs at the input a DC voltage.

Early, the electroerosion machines have used vacuum-tube rectifiers and after that, semiconductor diodes rectifiers.

A diode bridge rectifier for the three-phase system is presented in figure 2.

The Circuit is very simple and easy to design. For the filtration of the output voltage, a bulk capacitor is necessary, usually 10000 - 30000 μ F.

The electrical transformer has the iron core–tray. It has a big volume and a big weight. There are a lot of copper in the coils.

The Energy consumed for manufacturing all of the materials of the electrical transformer is high.

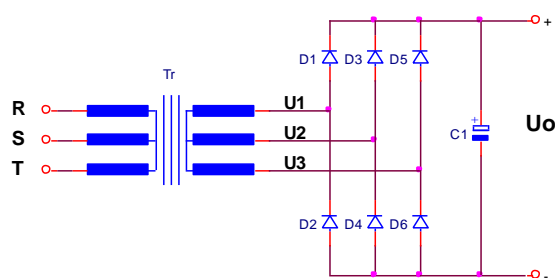


Fig.2. Power Supply for the Pulse Generator.

2. ADJUSTABLE POWER SUPPLY

The Pulse Generators that present the facility to select several levels of breakdown voltage need in front of them an adjustable power supply. In the modern EDM machines, numerical control has possibility to change the value of output voltage of power supply.

Many years ago, the controlled rectifiers with thyristors were usual. In the last years, the development of the fast power electronic devices (MOSFET, IGBT) gets to the development of the Switched Mode Power Supply (SMPS). The block diagram of the supply of the pulse generator, using a SMPS and a power factor circuit, is shown in figure 3.

The numerical value furnished by the computer is converted in an analogue reference voltage U_{ref} for the power supply. Analogue control provides the relation of proportionality between reference voltage and output voltage:

$$U_o = k \cdot U_{ref} \quad (1)$$

For the power supply which has several hundred Watt or more, is necessary an active Power Factor Correction (PFC).

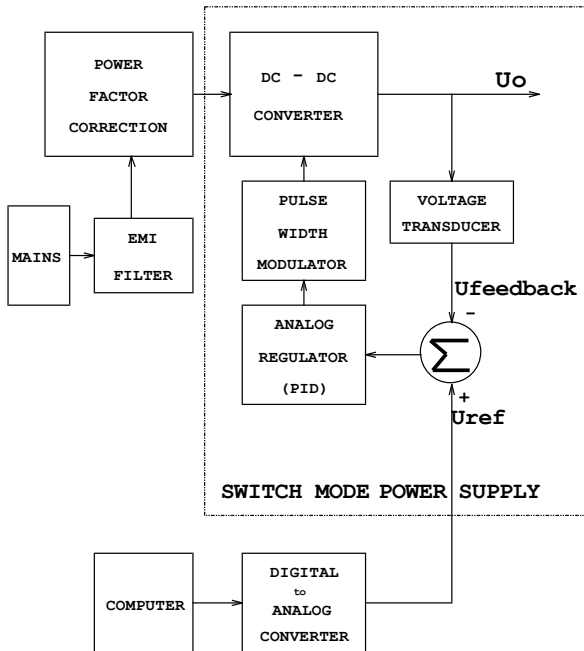


Fig.3. The supply of the pulse generator with adjustable DC voltage: block diagram.

The most important companies which products electronic devices have developed dedicated integrated circuits for SMPS and PFC. Generally a certain IC can be used for a certain topology of DC-DC converter.

The analog regulator is a circuit with operational amplifiers and a few passive components (resistors and capacitors). It compensates the open loop function transfer to makes the system stable.

Usually the DC-DC Converter is a based Buck Converter, like in figure 4:

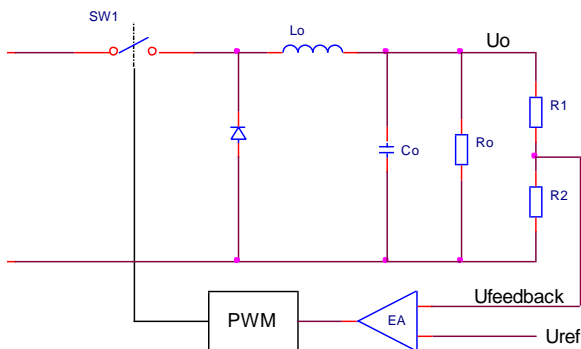


Fig.4. The Buck Converter-basic voltage loop.

- Ro is the equivalent load resistance
- EA is the error amplifier (regulator).

After redrawing the circuit according with the general control theory, the circuit's block diagram becomes:

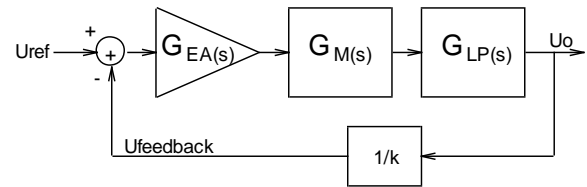


Fig.5. The Buck Converter: voltage mode loop bloc diagram.

- $G_{EA(s)}$ is the error amplifier (regulator) transfer function
- $G_{M(s)}$ is the transfer function of a PWM generator
- $G_{LP(s)}$ is the low-pass filter (Lo, Co, Ro) transfer function
- $1/k$ is the voltage transducer (R_1, R_2 voltage divider) transfer function if input impedance of error amplifier is very high.

$$\frac{1}{k} = \frac{U_{FB}}{U_o} = \frac{R_2}{R_1 + R_2} \quad (2)$$

The transfer function of a certain block $G(s)$ is the Laplace transform of the impulse response.

The open loop gain $G_{OL}(s)$ is :

$$G_{OL}(s) = G_{EA}(s) \cdot G_M(s) \cdot G_{LP}(s) \cdot \frac{1}{k} \quad (3)$$

The Bode diagram of this function can be easily drawing in logarithmic scale, multiplications correspond to sums and divisions correspond to subtractions.

$$G_{OL}(s)|_{dB} = G_{EA}(s)|_{dB} + G_M(s)|_{dB} + G_{LP}(s)|_{dB} - 20 \lg k \quad (4)$$

At the crossover frequency (f_{CO}), the open loop gain $G_{OL}(s) = 1$. In this point, with some simplifications, the criteria of stability can be stated as:

- the slope of $G_{OL}(s)$ -20dB/decade, and
- the phase margin at f_{CO} must be least 45° .

For the Buck Converter voltage mode loop error amplifier circuit can be like in figure 6:



Fig.6 Error amplifier network.

3. SWITCHED MODE POWER SUPPLY WITH DIGITAL CONTROL

Tanks to the technological progress, the manufacturing in the recent years of a certains microcontrollers that has inside all is necessary to make the digital control in Switched Mode Power Supply, became possible.

These devices are 16-bit processors based on the dsPIC30F and dsPIC33F, with three main building blocks:

- 16-bit microprocessor control unit
- Digital Signal Processor core
- Intelligent Power Peripheral:
 - PWM generator
 - High speed 10-bit analog to digital converter (ADC)
 - High speed comparator

There are high degrees of interconnections between the three high performance mentioned peripherals, which cooperate to the generation of control of the PWM output waveform without the direct intervention of the Central Processing Unit (CPU).

The bloc diagram of these devices is presented in figure 7.

The PWM signals can have the same frequency, or each one can operate independently with a duty cycle resolution as low as 1.05 ns.

The PWM can generate a set of triggers that will start the ADC operation, fault signals can stop the PWM operation, currents greater than a defined threshold in the internal comparators can inhibit the PWM outputs, and the PWM period counter can be reset by external signals to implement constant-off/on outputs.

The high speed 10-bit ADC can sample up to five signals at the same time and will always converts two input channels at a time (usually one current and one voltage).

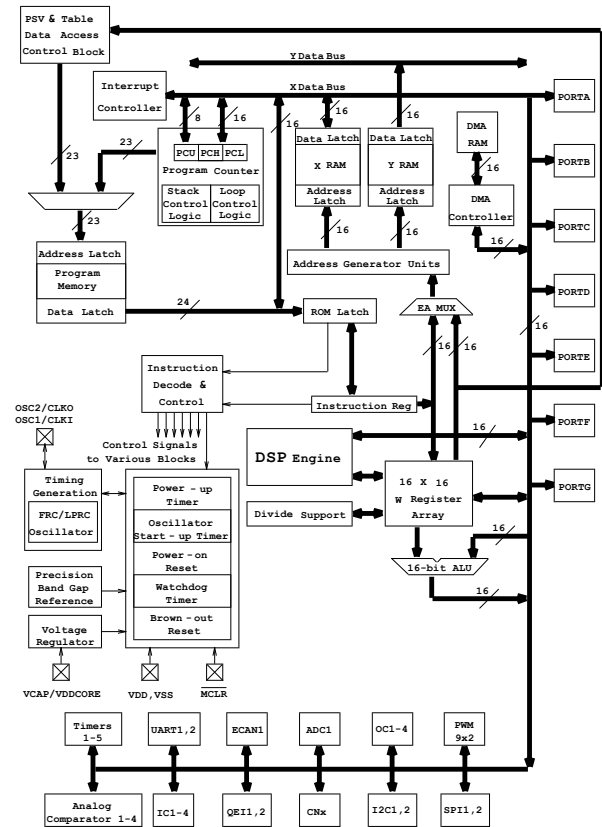


Fig.7. Bloc diagram of microcontrollers dsPIC33FJ32GS406/606/608/610 dsPIC33FJ64GS406/606/608/610.

Multiple triggers can start the converter operation.

The comparators can be used to detect over-current, or as in some current mode loops, be used to detect when the inductor current has reached a preset value.

While the peripherals mentioned take care of the greater part of the generation and management of the PWM, ADC, and comparator signals, the CPU and its DSP engine have plenty of time to perform the computations required to close the control loop in a digital solution.

The complexity and the flexibility of PWM modules make possible the implementation of the most DC-DC converter topologies.

To supply the pulse generator of a EDM machine a high power DC-DC converter is necessary.

The full bridge Zero Voltage Transition (ZVT) is the most used solution in the last years.

In the figure 8 is presented a adapted full bridge ZVT power supply with a microcontroller.

The full bridge is realized with MOSFET M1....M4. Two separate PWM modules

command the bridge, one module commands the left leg and the other one, the right leg. The adjustment of the output voltage is made by the phase shifting of the pulses generated by the PWM modules.

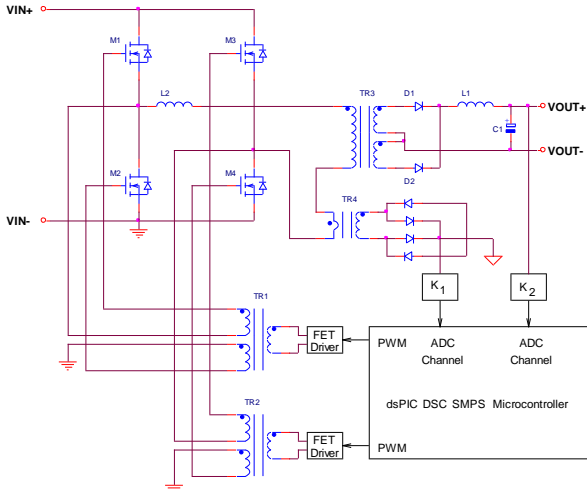


Fig.8. Full bridge ZVT power supply with microcontroller

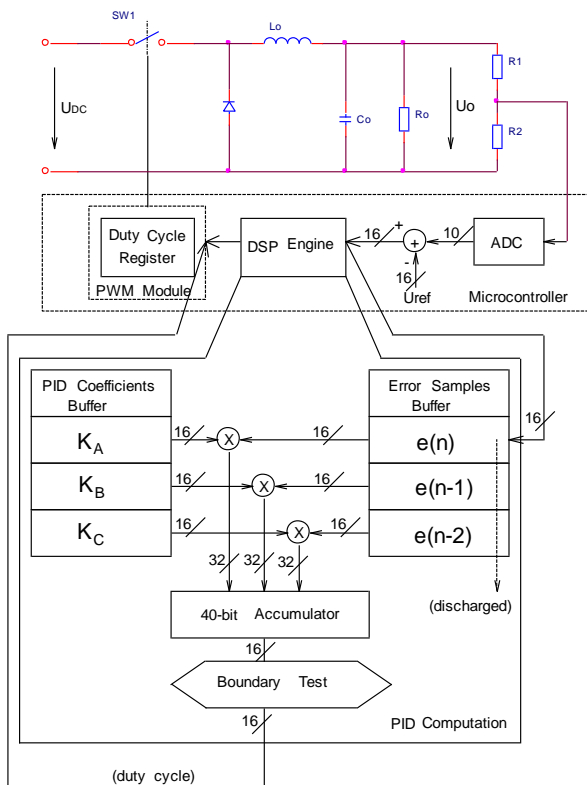


Fig.9. The Buck Converter voltage mode loop digital control: bloc diagram.

The information about the output voltage is furnished by the voltage transducer to one of the inputs of the ADC.

The information about the current through the bridge transistors is furnished by the current transducer (current transformer Tr4) to the other one of the inputs of the ADC.

The voltage loop maintains the output voltage at the desired value and the current loop protects the bridge transistor against over-current and prevent imbalance of the bridge.

The full bridge SMPS is based on the Buck Converter.

In the figure 9 is presented Buck converter voltage mode control loop implemented on a dsPIC DSC microcontroller.

4. INTELLIGENT POWER SUPPLY

In the block diagram of microcontroller (figure 3) it can be noticed the complexity of the 16-bit microcontroller.

The 16-bit by 16-bit, high-speed multiplier and the 40-bit accumulators allows a very efficient implementation of even high-complexity control algorithms. The operations required to implement a digital loop are basically a sequence of multiply/accumulate instructions. The DSP core is capable of implementing such instructions in a very efficient way.

To complete a control loop implementation some additional work is needed to set up initial conditions and usually, to check that the results are within a specified range; however, a full control loop computation is normally performed in 1 to 2 microseconds.

The authors estimated that remains enough resources to compute the energy consumed from the power mains, especially when is used a power factor correction circuit.

In figure 10 is presented a boost converter PFC circuits interleaved.

The microcontroller receives the information about main voltage by the K4 transducer and the information about the consumed current by the current transducer. This information is necessary in the correction of the power factor and can be used for the calculation of the consumed energy.

In the block diagram of microcontroller, it can be observed a number of communications modules: 2 Serial Peripheral interface (SPI) modules, 2 Inter-Integrated Circuit (I2C) modules, 2 Universal Asynchronous Receiver Transmitter (UART) modules and 1 Enhanced Controller Area Network (ECAN) module.

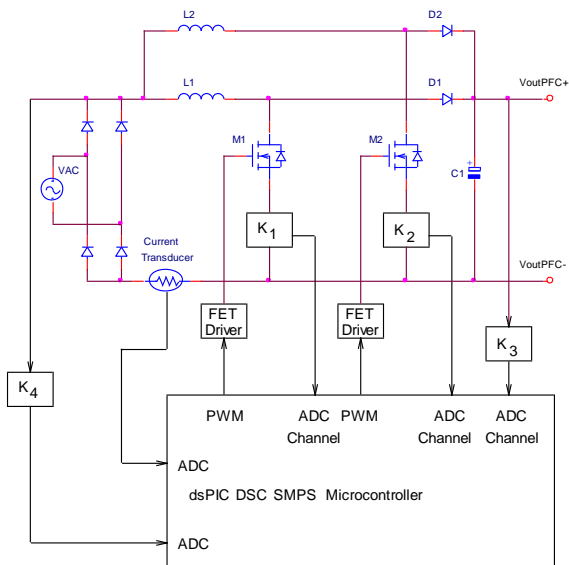


Fig.10. Boost converter PFC circuits interleaved.

The various applications with microcontroller, power supply, pulse generator, motor drive systems can communicate each other.

The information about the consumed energy can be transmitted to the central processor or to the outside of the machine (internet, local area network and so on).

5. CONCLUSIONS

With the presented microcontrollers can be realized the power supply for the pulse generator of EDM machine.

The power supply is working in the switched mode of electronic power devices (IGBT or MOSFET).

It has a digital control and many possibilities to communicate.

Inner microcontroller of power correction circuit can calculate the electrical consumed energy without additional sensors to acquire mains voltage and current consumed information.

This information can be used by the central processor for optimize the technological process considering the electrical consumed energy.

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