Maximizing Power Transfer to the Remote Terminal of PCM4 System

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Abstract – **This paper presents a method that allows maximum power transfer from Central Office Terminal (COT) to Remote Terminal (RT) of PCM 4 system for TELECOM use. This is achieved by employing a PWM controller as a Voltage Controlled Oscillator. The basic theory of FLYBACK converter is also presented in order to show the roots of the idea. The modified DC/DC converter was built and successfully tested. Performance measurements in the laboratory show that the goal is met.**

Keywords – **PCM4, Central Office Terminal, Remote Terminal, FLYBACK, PWM, DC/DC converter.**

I. INTRODUCTION

Telecom operators in the whole world use PCMx systems offering x (4, 6, 8 or 11) voice channels at 64kbps due to lack of copper cables (subscriber loops). Usually in urban areas there is unused switching capacity and lack of installed subscriber loops. The most popular is PCM4 which offers 5km reach, requires a lower voltage feed for remote powering and 4x64 kbps channels. This system consists of two main elements: COT (Central Office Terminal) and RT (Remote Terminal). RT is connected to COT via Unshielded Twisted Pair. The COT is powered from Central Office 48V battery and generates high voltage designed to power the Remote Terminal via twisted pair. The high voltage is no more than 200V and the current is limited to less than 60mA. Both power supplies are realized as a flyback converter for simplicity and lower cost.

II. PRINCIPLE OF FLYBACK CONVERTER

The basic flyback converter circuit is shown in Fig. 1. While the primary power switch (MOSFET) is on, the energy is taken from input and stored in the transformer. Actually it is a coupled inductor, because the current does not flow at the same time in the primary and secondary side. At the secondary the diode is reverse biased and the load takes energy from the output capacitor. When the power switch turns off, the output diode is forward biased and the energy is transferred to output capacitor and the load. There are two basic modes of operation. The first mode is discontinuous conduction mode (DCM) in which all of the stored energy is transferred to secondary during the time the power switch is OFF and the current has triangular shape. The second mode is continuous conduction mode (CCM) in which the part of the stored energy remains in the transformer when power switch turns on again and the current has trapezoidal shape (Figs.2 and 3). DCM converter requires a transistor and diode with higher current rating and bigger capacitors with low ESR (equivalent series resistance) and vice versa. For a given converter the operating mode depends on the switching frequency, input voltage and output load.

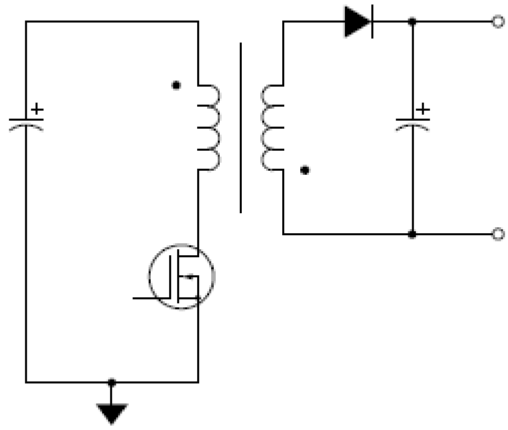

Fig. 1. Flyback converter

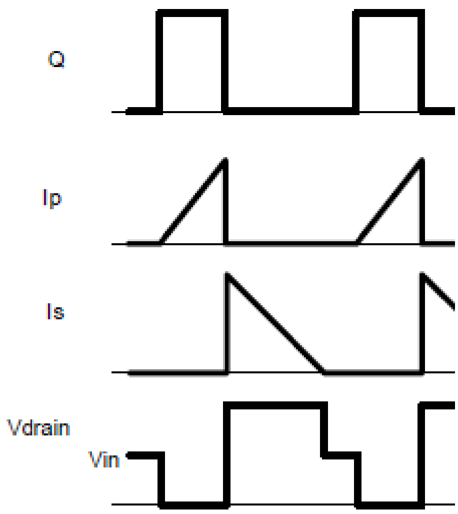

Fig. 2. DCM Waveforms

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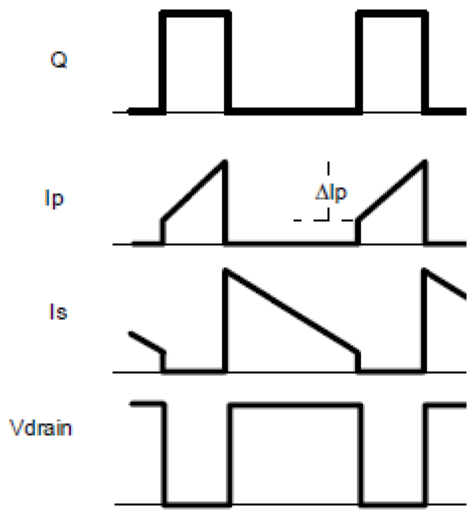

Fig. 3. CCM Waveforms

III. PROBLEM SOLUTION

Remote feeding voltage is 150V and current is limited to 50mA. The maximum loop length is 5km with 0.4mm copper wire and with DC loop resistance around 1350ohms. That means the power available at the end of the twisted pair is 4.125W (83Vx50mA) because the voltage drop over the loop is 67V. If we design the converter for RT with minimum operating voltage of 85V, at the beginning of twisted pair he will draw only 4.125W instead of 7.5W (150Vx50mA) available. The reason for this is that the converter is constant power load. When all four subscribers are off the hook, the power consumption of RT is around 5.5W which means that use of VRLA (Valve Regulated Lead Acid) 12V battery for RT is a necessity. Obviously we need the solution which maximizes power transfer from COT to RT automatic.

Again the magnitude of stored energy in flyback transformer is given in Eq. (1):

$$W = \frac{LI_p^2}{2} \tag{1}$$

where I_p is peak primary current.

The average power is given in Eq. (2)

$$P = \frac{W}{T} = \frac{LI_p^2}{2T} = \frac{1}{2} LI_p^2 f \tag{2}$$

As we see the power is directly proportional to the switching frequency. Varying the frequency we can change the power delivered to the Remote Terminal. We can achieve this by employing a PWM controller (in our case UCC2804 from Texas Instruments) as a voltage controlled oscillator (Fig. 4).

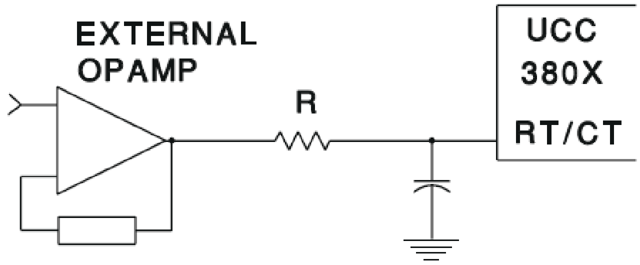

Fig. 4. Using PWM as a VCO

The oscillator section of the UCC2804 has single pin programming. It requires only a resistor to the reference voltage and capacitor to the ground. Using external operational amplifier we can change charging current and thus the frequency.

If we make the loop that regulates the feeding current to slightly lower value from 50mA, we can maximize power transfer from COT to RT using a handful of elements. The circuit is given in Figs. 5 and 6.

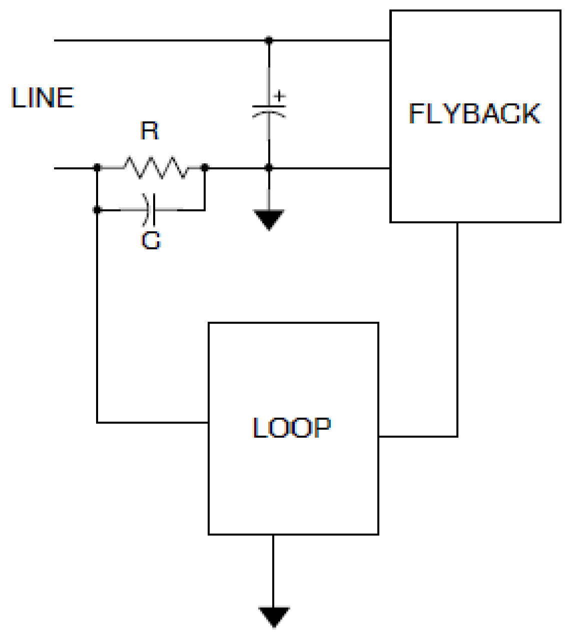

Fig. 5. Basic circuit

Voltage from the current sensing resistor R at the end of the subscriber line is fed via integrator (operational amplifier with R1 and C1) to the oscillator in PWM controller UCC2804 in order to regulate the frequency. Small adjustments of components values are needed in order to make the loop stable.

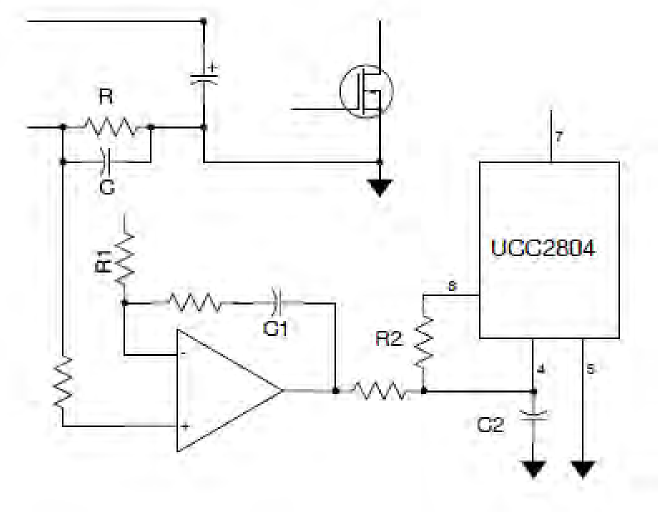

Fig. 6. More detailed circuit

IV. Realization

At the first time flyback converter for RT was built without this automatic feature. Next step was the static test with single resistor and external voltage source. Measurements are taken for different line voltages between 85V and 150V using external voltage to correct the switching frequency in order to maximize the power transfer. The results were very good, so that the complete loop with integrator was built on a separate printed circuit board. Again the measurements are taken, this time only varying the line voltage. Nearly constant feeding current is achieved. The measurements results are given in Table I.

TABLE I
MEASUREMENTS RESULTS

V_L[V]	T[μs]	F[kHz]	I[mA]	P[W]
85	8.7	115	48.8	4.148
90	8.4	119	48.8	4.392
95	8.0	125	48.8	4.636
100	7.6	131	48.8	4.880
105	7.3	137	48.8	5.124
110	7.0	143	48.8	5.368
115	6.8	147	48.9	5.623
120	6.3	159	48.9	5.868
125	6.0	167	48.9	6.112
130	5.7	175	48.9	6.357
135	5.5	182	48.9	6.601
140	5.3	189	48.9	6.846
145	5.2	192	48.9	7.090
150	5.1	196	48.9	7.335

The drain waveforms of the RT flyback converter are given in Figs. 7, 8 and 9.

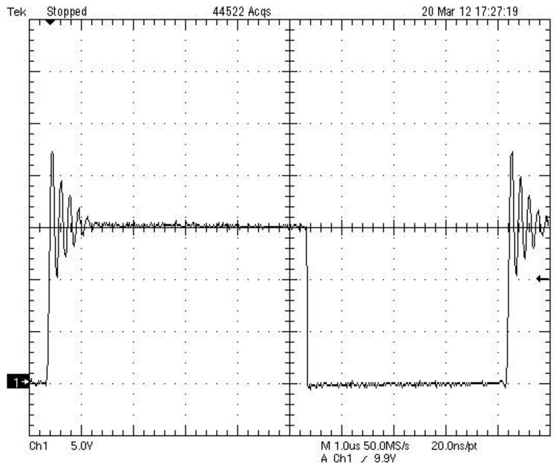

Fig. 7. Drain waveform at 85V

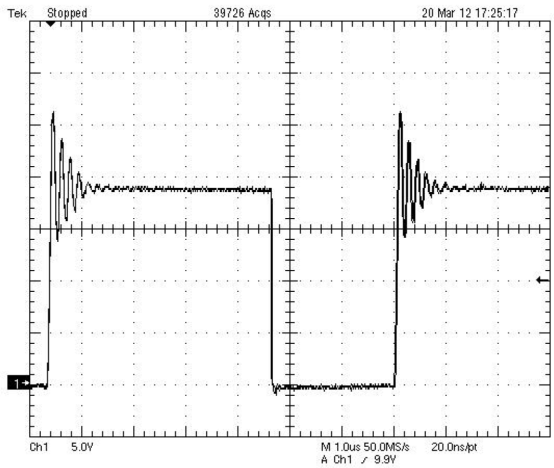

Fig. 8. Drain waveform at 125V

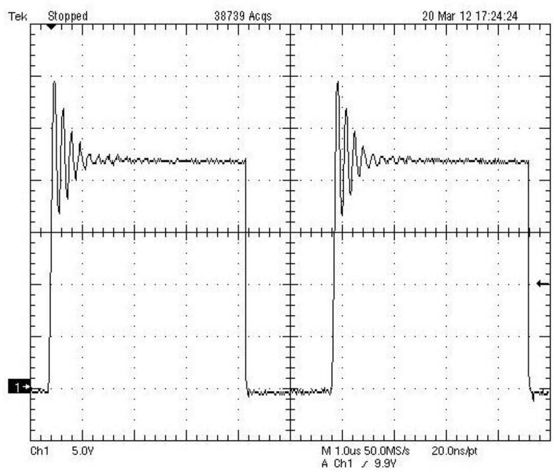

Fig. 9. Drain waveform at 150V

As seen on the waveforms the converter is working in CCM mode. Ringing in the drain waveform of the power switch is not a problem because a maximum drain voltage is well within specifications of used BUZ76A.

All measurements are repeated in a climatic chamber at temperatures between -10º and +55º Celsius.

The picture of the converter prototype is given in the Fig. 10. The size of the board is 100x160mm. Small printed circuit board in the bottom of the picture is a redesigned circuit.

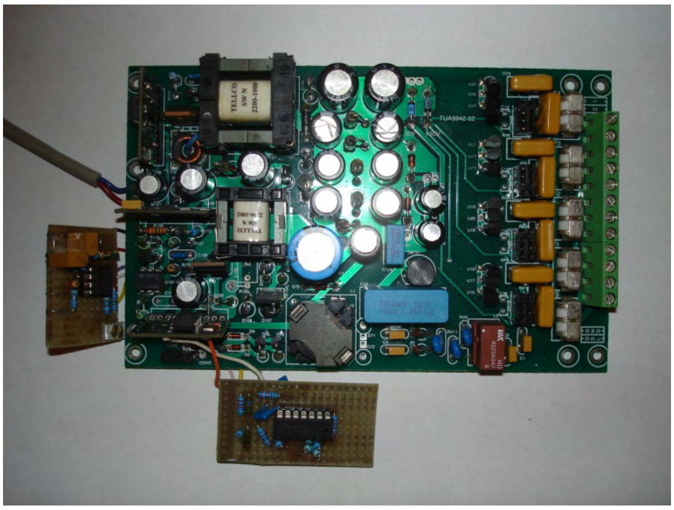

Fig. 10. The converter prototype

V. Conclusion

This paper proposes the simple modification of FLYBACK DC/DC converter in order to maximize the power transfer from Central Office Terminal to Remote Terminal via subscriber line. The topology is simple and easy to adjust. The converter already requires knowledge in loop stability so it is not a problem to compensate new current loop. The prototype was built and successfully tested.

Acknowledgement

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References

[1] Mindspeed, PCMx Voice Pair Gain (VPG) Framer Bt8954, Data Sheet, www.mindspeed.com
[2] Texas Instruments, "Low Power BiCMOS Current Mode PWM", slus270d Data Sheet, www.ti.com
[3] Texas Instruments, "UCC3800/1/2/3/4/5 BICMOS CURRENT MODE CONTROL ICs", slua149 Application Note, www.ti.com
[4] Texas Instruments, "Under the Hood of Flyback SMPS Design", slup261 Power Supply Design Seminar, www.ti.com
[5] Maxim Integrated Products, "Designing Compact Telecom Power Supplies", AN1062 Application Note, www.maxim-ic.com