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Recent Topics in Power Management Circuits

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***Abstract*— This paper summarizes recent research at the author's laboratory into power management circuitry, including: (1) Envelope-tracking power supplies for base station power amplifiers, (2) Digital PWM generator circuitry, (3) Spread-spectrum clocking for EMI reduction in digitally-controlled power supplies, (4) High-efficiency coupled-inductor DC-DC converters with fast response and low ripple, and (5) Single-inductor multi-output DC-DC converters.**

I. Introduction Analog circuits can be broadly classified into three categories: (i) baseband circuits, (ii) RF circuits, and (iii) power management circuits. Many university laboratories that are doing research into analog circuitry focus on baseband circuitry and/or RF circuitry. However the author strongly believes that power management circuitry is also very important, because of the interesting technological challenges, increasing demands for energy conservation, and the huge market demand for power circuitry. Hence the author's laboratory is working with power electronics laboratories and doing industry-supported research into power management circuitry. This paper introduces some of the research projects.

II. Envelope-Tracking PSUs for Base Station PAs We have developed a new architecture for envelope-tracking Power Supply Units (PSUs) for base station power amplifiers (PAs) (Fig.1(a)) [1]. Using variable, rather than fixed, power supply voltage (Vdd) can greatly improve efficiency – this technique is especially effective for W-CDMA and OFDM, where the peak signal power is much higher than the average power. The proposed multiphase DC-DC converter uses multiple switching (and voltage follower) circuits, each optimized for a different envelope frequency, to realize both high efficiency and wide bandwidth (Fig.1(b)).

III. DPWM generator circuit Digitally-controlled DC-DC converters are becoming prevalent, and Digital Pulse Width Modulation (DPWM) generators are a key component of them. We have developed a new architecture for high-resolution DPWM generators (Fig.2) [2]; PWM time resolution is determined by the difference between two (or more) gate delays, while that of conventional DPWM circuits is determined by the gate delay itself. The proposed DPWM circuit can achieve fine time resolution with small circuitry, and has low power consumption. We have also developed a systematic design method, based on the extended Euclidean algorithm, for these DPWM circuits.

IV. Spread-spectrum clocking for EMI reduction In switching regulators using PWM, switching noise and harmonic noise concentrated in a narrow spectrum around the switching frequency can cause severe EMI. Spread-spectrum clock modulation can be used to minimize EMI. We have developed spread-spectrum clock modulation algorithms which are a combination of PPM (pulse position modulation) and ASM (asynchronous modulation) for EMI reduction in digitally-controlled DC-DC converters (Fig.4) [3]. It is difficult to realize complex spread-spectrum clocking with analog controllers, however we have shown that it is relatively easy to implement spread-spectrum EMI-reduction using digital control.

V. Coupled-inductor converters The optimizing of inductor values for the best tradeoff between efficiency and transient response is a key issue in switching DC-DC converter design (Fig.4); using a smaller inductor improves the response to load changes but increases steady-state current ripple and decreases circuit efficiency, and vice versa. Using coupled inductors as the magnetic component in multiphase buck DC-DC converters is expected to solve this tradeoff issue. We have analyzed characteristics of the multiphase buck converter with coupled inductors and derived the equivalent inductance [4]. We have also examined and verified its characteristics – low per-phase ripple current and fast response – by circuit simulation and experiments.

VI. Single-Inductor Multi-Output Converter Single Inductor Multiple Output (SIMO) switching DC-DC converters have received a lot of attention recently: they can provide more than one output while requiring only one off-chip inductor – this reduces converter size and also reduces overall cost, since the inductor is the highest-cost component of a switching converter. We have investigated single inductor dual-output boost and buck-boost converters that operate in Pseudo-Continuous Conduction Mode (PCCM) (Fig.5) [5]. Important research topics include control circuit design, reducing the number of power MOSFETs, and reducing switching noise.

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References

[1] A. Kanbe et. al., "New Architecture of Envelope Tracking Power Amplifier for Base Station," IEEE APCCAS (Dec. 2008).
[2] I. Mori, "High-Resolution DPWM Generator for Digitally Controlled DC-DC Converters", IEEE APCCAS (Dec. 2008).
[3] I. Mori, et. al., "EMI Reduction by Spread-Spectrum Clocking in Digitally-Controlled DC-DC Converters", IEICE Trans. Fundamentals (April 2009).
[4] S. A. Wibowo, et. al., "Analysis of Coupled Inductors for Low-Ripple Fast-Response Buck Converter," IEICE Trans. Fundamentals (Feb. 2009).
[5] S. A. Wibowo, et. al., "A Single-Inductor Dual-Output DC-DC Converter," IEICE 22nd Circuits and Systems Workshop in Karuizawa (April 2009).

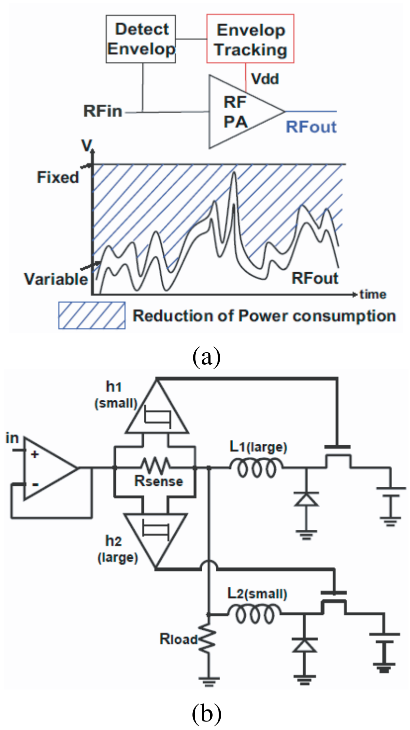

Fig. 1. (a) Envelope tracking power supply. (b) Proposed envelope tracking power supply circuit [1]. PA is modeled with Rload.

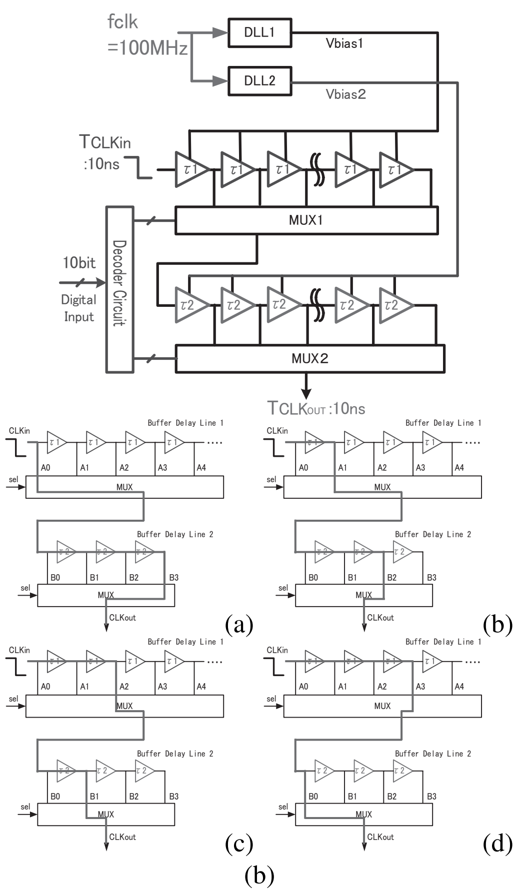

Fig. 2. Proposed two-delay-line DPWM generation and its operation [2].

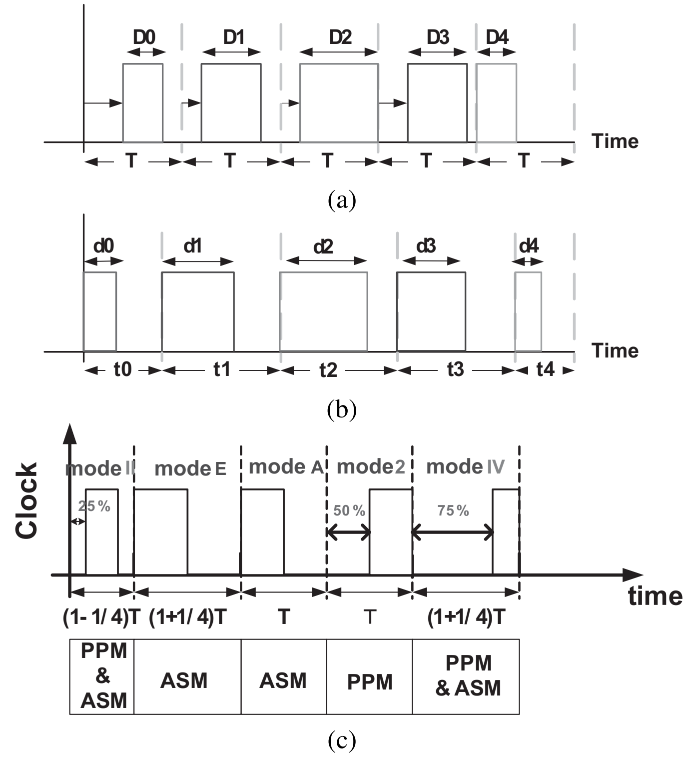

Fig. 3. (a) Clock with PPM modulation. (b) Clock with ASM modulation. (c) Proposed spread spectrum clock implemented with a digital controller [3].

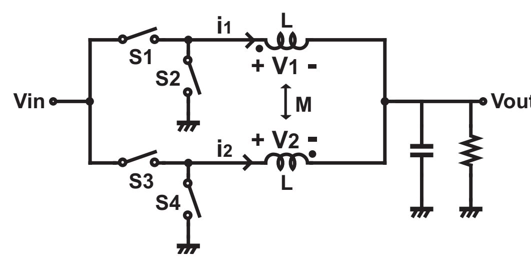

Fig. 4. Two-phase coupled-inductor buck converter [4].

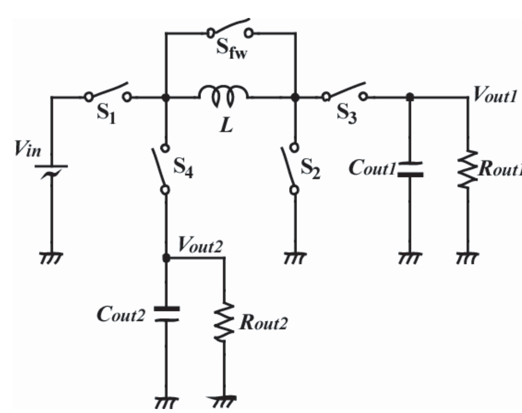

Fig. 5. SIDO boost and buck-boost converter [5].