Ph. D. Dissertation Title:

Study of Multiphase Networks,

Noise Reduction for DC-DC Converters, and

Stability Test for Electronic Systems

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Ph. D. Dissertation Summary

This dissertation deals with design and testing aspects of three analog circuits: multiphase network, DC-DC converter, analog circuit with negative feedback configuration. The focus of this work is the fundamental concepts for network analysis theory to acquire good yield of their performance, low noise, and high stability at the mass production testing stage as well as to obtain design margin and realize reliable verification. Especially, we propose the widened superposition principle as a new concept. The comparison measurement and the alternating current conservation are also used for analyzing, simulating and predicting their behaviors.

Multiphase Networks

We show that by applying the widened superposition principle, the transfer functions of multiphase networks are easily derived. Multiphase networks are widely used in wireless communication systems such as polyphase filters, complex filters, and quadrature signal generation circuits. From the view point of the complex function, we propose a widened superposition principle to derive the transfer function of a general network. The proposed principle states that energy at one place is proportional with their input sources and the resistance distances of transmission spaces. At one node, that the incident currents are equal to the transmitted currents. So, the incident energy sources and the transmitted energy source are separated completely. The term of "widened superposition principle" means that we can solve all sources at a time. To demonstrate its effectiveness, we derive the transfer function of a sixth-order complex filter, which needs very tough calculation conventionally, but becomes a relatively simple task with the proposed method. These results can also lead to their I, Q –mismatch measurement and evaluation.

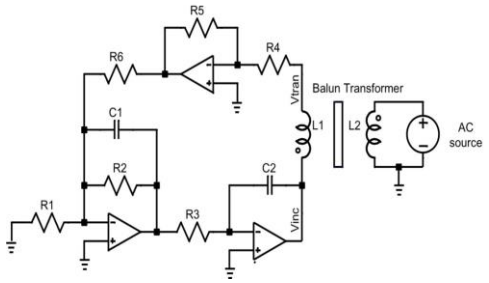
Noise Reduction for DC-DC Converters

We show that the output voltage ripple of a DC-DC converter is kept vary small by a spread spectrum technique and an LC harmonic notch filter. The passive inductor in this notch filter is also replaced by a designed impedance converter. These techniques can improve the DC-DC converter yield significantly at the mass production testing stage. They are based on the fact that as an adaptive feedback network, the sampling level of the desired output voltage of a DC-DC converter is used to compare with a referent voltage. Therefore, the power stage of the converter defines the behavior of the total systems. Energy of the DC-DC converter is maximally propagated based on the balance charge-discharge time of the load capacitor at the power stage.

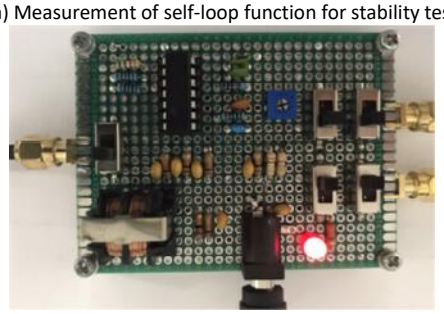
Stability Test for Electronic Systems with Feedback Configuration

To derive the self-loop function in a transfer function of analog filter, amplifier, or operational amplifier network with negative feedback configuration, we show the proposed comparison measurement and the alternating current conservation methods by revisiting the feedback theory. Our stability test is performed with closed-loop configuration and a transformer by the investigation of the phase margin at unity gain of a self-loop function. The theoretical analysis of the phase margin is verified by MATLAB calculation, SPICE simulation, and the practical measurements. The operating regions of these systems can be over-damping, critical damping, and under-damping. In case of under-damping, ringing causes the damped oscillation noise and makes the system unstable. The operating region of a general transfer function can be theoretically defined based on the Pascal's triangle. The proposed method is useful especially for high-order network test.

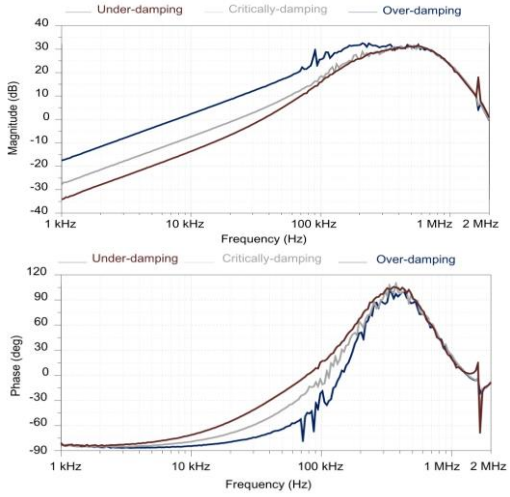
Stability Test for Second-order Low-pass Filter



(a) Measurement of self-loop function for stability test



(b) Implemented circuit.



(c) Measurement results

Measurement of 2nd-order LPF self-loop function with closed-loop configuration and utilizing transformer for stability test

Operating regions:

- Over-damping: Phase margin → 90 degrees.
- Nearly Critical damping: Phase margin →76 degrees.
- Under-damping: Phase margin → 30 degrees.

Published papers

Multiphase Networks

[1] M. Tran, N. Kushita, A. Kuwana, H. Kobayashi, "Pass-band Gain Improvement Technique for Passive RC Polyphase Filter in Bluetooth Low-IF Receiver using Two RC Band-stop Filters", Applied Mechanics and Materials, 2020. (accepted)

[2] M. Tran, A. Hatta, A. Kuwana, H. Kobayashi, "Design of Sixth-order Passive Quadrature Signal Generation Network based on Polyphase Filter", 15th IEEE ICSICT, Nov. 2020. (accepted)

[3] M. Tran, N. Kushita, A. Kuwana, H. Kobayashi, "Flat Pass-Band Method with Two RC Band-Stop Filters for 4-Stage Passive RC Polyphase Filter in Low-IF Receiver Systems", 13th IEEE ASICON, Oct. 2019.

[4] M. Tran, N. Kushita, A. Kuwana, H. Kobayashi, "Mathematical Model and Analysis of 4-Stage Passive RC Polyphase Filter for Low-IF Receiver", J. Mech. Elect. Intel. Syst. vol. 3, no. 2, May 2020.

Noise Reduction for DC-DC Converters

[5] M. Tran, Y. Sun, N. Oiwa, Y. Kobori, A. Kuwana, H. Kobayashi, "Mathematical Analysis and Design of Parallel RLC Network in Step-down Switching Power Conversion System", J. Mech. Elect. Intel. Syst. vol. 3, no. 2, May 2020.

[6] M. Tran, Y. Sun, Y. Kobori, A. Kuwana, H. Kobayashi, "Design Proposal for Inductor Type Buck Converter in Bluetooth Receiver Chip with Overshoot Cancellation and Ripple Reduction Technique", Applied Mechanics and Materials, 2020. (accepted)

[7] M. Tran, Y. Sun, N. Oiwa, Y. Kobori, A. Kuwana, H. Kobayashi "Fast Response, Small Ripple, Low Noise Switching Converter with Digital Charge Time Control and EMI Harmonic Filter", J. Mech. Elect. Intel. Syst. vol. 2, no. 1, pp.14-23, Dec. 2019.

[8] M. Tran, Y. Kobori, A. Kuwana, H. Kobayashi, "Design of LC Harmonic Notch Filter for Ripple Reduction in Step-down DC-DC Buck Converter", 15th IEEE ICSICT, Nov. 2020. (accepted)

[9] M. Tran, Y. Sun, Y. Kobori, A. Kuwana, H. Kobayashi, "Minimum Output Ripple and Fixed Operating Frequency Based on Modulation Injection for COT Ripple Control Converter", 13th IEEE ASICON, Oct. 2019.

[10] M. Tran, Y. Sun, Y. Kobori, A. Kuwana, H. Kobayashi, "Overshoot Cancelation Based on Balanced Charge-Discharge Time Condition for Buck Converter in Mobile Applications", 13th IEEE ASICON, Oct. 2019.

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[12] M. Tran, N. Miki, Y. Sun, Y. Kobori, H. Kobayashi, "EMI Reduction and Output Ripple Improvement of Switching DC-DC Converters with Linear Swept Frequency Modulation", 14th IEEE ICSICT, Nov. 2018.

Stability Test for Electronic Systems

[13] M. Tran, A. Kuwana, H. Kobayashi, "Derivation of Loop Gain and Stability Test for Low Pass Tow-Thomas Biquad Filter", 10th Int. Conf. CCSEA 2020, July 2020, David C. Wyld et al. (Eds): CCSEA, BIoT, DKMP, CLOUD, NLCAI, SIPRO – 2020, Vol. 10, No. 10, pp. 175-194, 2020. CS & IT - CSCP 2020 DOI: 10.5121/csit.2020.101014.

[14] M. Tran, A. Kuwana, H. Kobayashi, "Design of Active Inductor and Stability Test for Passive RLC Low Pass Filter", 10th Int. Conf. CCSEA 2020, July 2020, David C. Wyld et al. (Eds): CCSEA, BIoT, DKMP, CLOUD, NLCAI, SIPRO – 2020, Vol. 10, No. 10, pp. 175-194, 2020. CS & IT - CSCP 2020 DOI: 10.5121/csit.2020.101014.

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[16] M. Tran, A. Kuwana, H. Kobayashi, "Derivation of Loop Gain and Stability Test for Low Pass Tow-Thomas Biquad Filter", 6th Int. Conf. SIPRO, July 2020.

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