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Derivation of Loop Gain and Phase from Output Impedances in DC-DC Buck Converter

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We propose a method to derive the loop gain from the open-loop and closed-loop output impedances in dc-dc buck converter. This enables to measure the loop gain without injecting a signal into feedback loop, i.e. without breaking the feedback loop; hence the proposed method can be applied for the control circuits implemented on an IC. Our experiment results show that the loop gain obtained from the proposed method matches very well with the one from the conventional method.

Fig. 1 shows a control block diagram of dc-dc buck converter, and the converter output impedance Z_{oc} in the closed loop is defined as

$$Z_{oc} \equiv \left.\frac{\Delta V_o}{-\Delta I_o}\right]_{\Delta V_{ref}=0, \Delta V_{in}=0} = \frac{Z_o}{1+T}\ , \tag{1}$$

Where Z_o is the output impedance of the open loop. We consider that based on Eq.(1), the loop gain T can be derived from both the output impedances; the loop gain and phase are obtained as follows:

$$20\log_{10}|T| = 20\log_{10}\left(\frac{|Z_o - Z_{oc}|}{|Z_{oc}|}\right), \tag{2}$$

$$arg(T) = arg(Z_o - Z_{oc}) - arg(Z_{oc})\ . \tag{3}$$

Fig. 2 shows comparison of the loop gains obtained in the experiment. We see that the conventional method and the proposed method have good agreements, and we consider from these results that sufficient evaluation of the phase margin and gain margin is feasible with the proposed method.

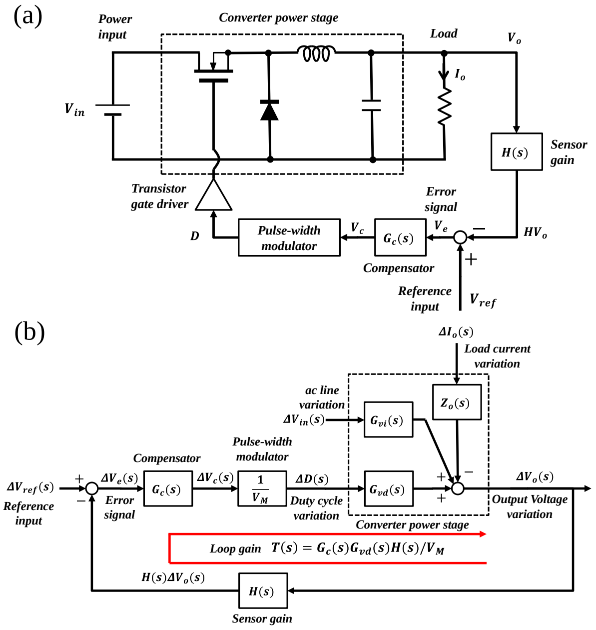

Fig. 1. Feedback loop for regulation of the output voltage in dc-dc buck converter. (a) Feedback loop block diagram. (b) Functional block diagram of the feedback system [1].

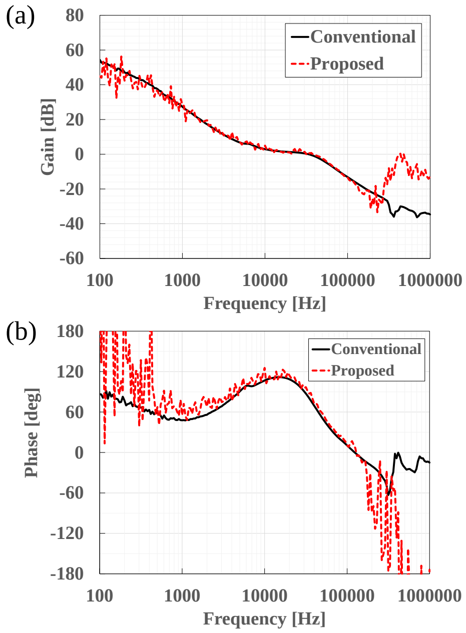

Fig. 2. Comparison of loop gain in experiment. (a) Gain. (b) Phase.

[1] R. W. Erickson, D. Maksimovic, Fundamenteals of Power Electronics, 2nd Edition, Springer, NY (2001).