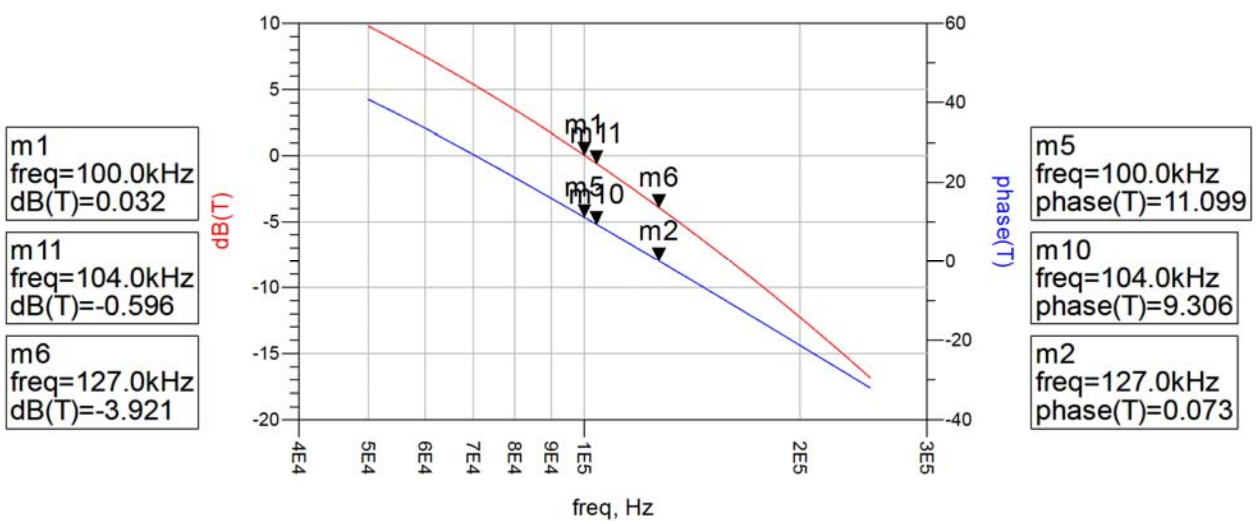
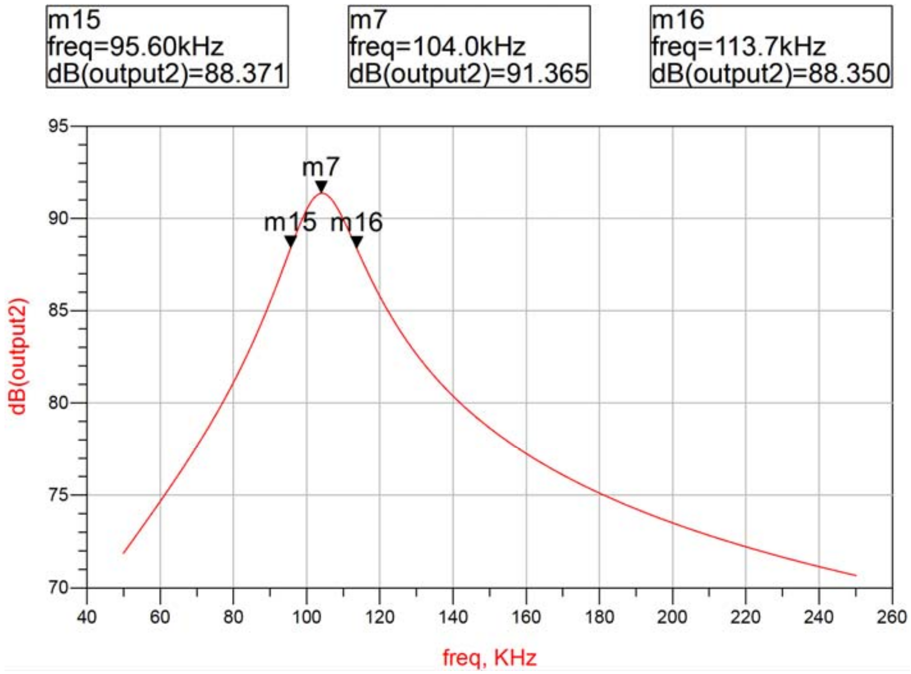
So how does this non-invasive measurement relate to phase margin and gain margin?

It doesn't, at least not directly. Since stability is an assessment of the proximity of the gain vector to the singular unstable point, (1,0) on the complex plane, we can assess it, via Q, as 1/(1-T) (or 1+T depending on where we account for the negative feedback). This means that there is no such thing as "gain margin" or "phase margin", but stability margin as a measure of the proximity of the vector gain, T to (1,0).

We can equate the stability to an equivalent phase margin by assuming the magnitude of the gain vector to be 1 and solving for the Q.

In our simple example below, the measured Q from the output impedance is 5.77 and we can equate that with 1/(1-T).





The Q of the output impedance is 104kHz/(113.7kHz-95.6kHz) or 5.76, almost identical to that determined from the length vector. Again this does not reflect the bandwidth, gain margin or phase margin, but the least stable point, as represented by the point closest to the singular unstable point, (1,0).

The Q of the circuit can be evaluated as 1/1-T

if we wish to equate the Q with the equivalent as a gain margin or a phase margin we can easily do so

$$Q = \frac{1}{1 - T}$$

$$T = \text{mag}\cdot(\cos(\theta) + \sin(\theta))$$

substituting for T

$$Q = \frac{1}{1 - [\text{mag}\cdot(\cos(\theta) - \sin(\theta))]}$$

and this can be solved for phase margin by setting the magnitude of the vector to 1, which is the definition of phase margin, and solving for phase margin.

$$Q = \frac{1}{1 - [1 \cdot (\cos(\theta \cdot deg) - \sin(\theta \cdot deg))]}$$

$$PM(Q) := \frac{180}{\pi} \cdot atan2\left(\frac{Q - 1 + 1 \cdot \sqrt{Q^2 + 2 \cdot Q - 1}}{2Q}, \frac{-Q + 1 + \sqrt{Q^2 + 2 \cdot Q - 1}}{2Q}\right)$$

$$PM(5.77) = 9.228$$

And this is in very good agreement with the simulated phase at the frequency closest to the singular unstable point (1,0) which has a gain magnitude very close to 1.

In the same way, we can solve this equation assuming a phase of 0 Deg, which is the definition of gain margin and solving for mag.

$$Q = \frac{1}{1 - T}$$

And T lies on the X axis, since the gain margin is defined as 0 Deg so T is represented by the magnitude of the equivalent gain

$$mag := T$$

$$Q = \frac{1}{1 - mag}$$

solving for the magnitude as a function of Q is

$$\mathrm{mag}(Q) := \frac{Q-1}{Q}$$

$$\mathrm{mag}(5.77) = 0.827$$

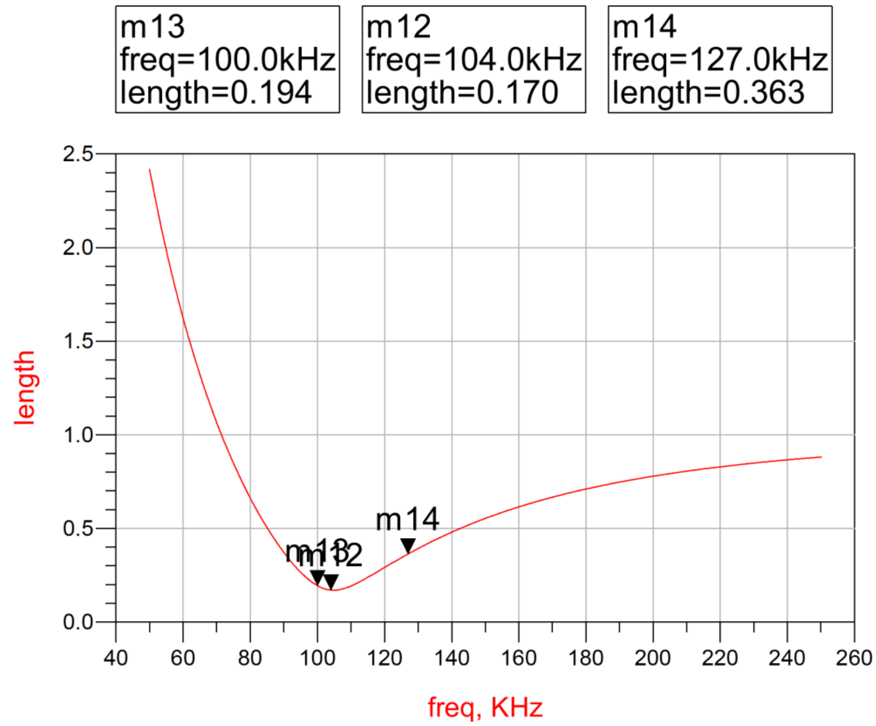
and the gain margin is the distance from the singular point (1,0) to this gain magnitude

$$\mathrm{GM}(Q) := 1 - \mathrm{mag}(Q)$$

$$\mathrm{GM}(Q) := \frac{1}{Q}$$

$$\mathrm{GM}(5.77) = 0.173$$

Which represents the equivalent magnitude distance between the point (1,0) and the gain curve



The simulated distance from the singular unstable point, (1,0) shows the minimum distance as 0.17, in excellent agreement with our calculated result of 0.173. This is based on the evaluation of the magnitude that results in a Q of 5.77 and assumed to lie on the X axis (0 Deg)

We can represent this stability as either an equivalent phase margin of 9.2 Deg or an equivalent gain margin of 0.173 (as a magnitude). Either of these really just represents a Q of 5.77 that is a result of the proximity of the gain vector to the singular unstable point (1,0).