問題２

MOSトランジスタは非線形特性があるため，動作の解析が困難である．そこで，バイアス点の近傍の微小範囲で解析を行う．この手法を小信号解析と呼ぶ．短チャネルMOSトランジスタの小信号モデルは図１のように書ける．ただし，基板バイアス効果を無視する．また，相互コンダクタンスをg_{m}，トランジスタの出力抵抗をr_0，ゲート・ソース間電圧の小信号成分をv_{gs}とする．記号は凡例に従う．以下の問に答えよ．

(1) 図２のように抵抗負荷R_{D}を付けたソース接地回路の小信号等価回路を示せ．さらに，電圧増幅率A_{V}，入力抵抗R_{in}，出力抵抗R_{out}を式で示せ．

(2) 図３は，図２の抵抗負荷R_{D}の代わりに定電流源を付けたソース接地回路である．この回路の小信号等価回路を示せ．また，電圧増幅率A_{V}を式で示せ．

(3) 定電流源の作り方として，図４のような回路を使うことが考えられる．この時の小信号等価回路を示せ．また，電圧増幅率A_{V}を式で示せ．

(4) 図５のような回路を使って，図４における定電流源としてのMOSにゲートバイアスV_{b}を与える．この回路では，I_{in}と同じ大きさの電流をいつでもI_{out}に流すことができる．このことに着目し，図６の差動増幅回路の差動ゲインを求めよ．

(5) 図７のように差動増幅回路に容量で帰還を掛ける．この差動増幅回路の閉ループゲインを求めよ．

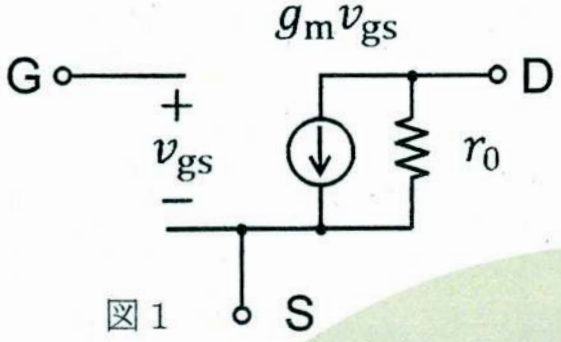


図1

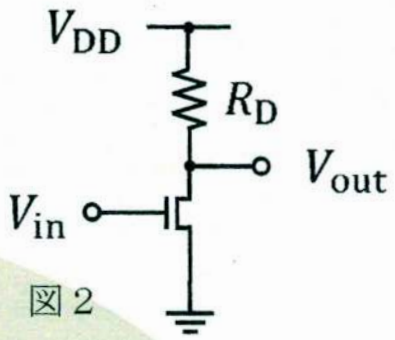


図2

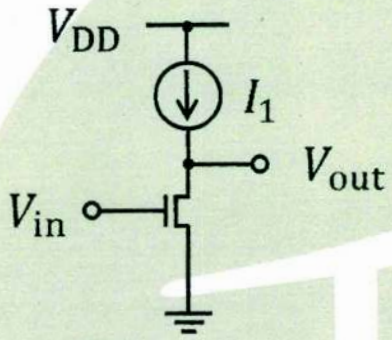


図3

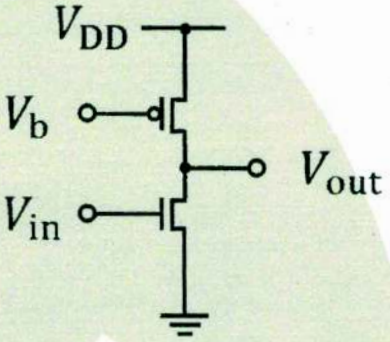


図4

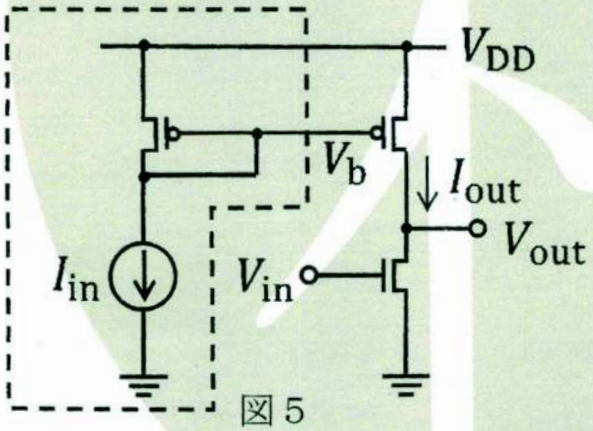


図5

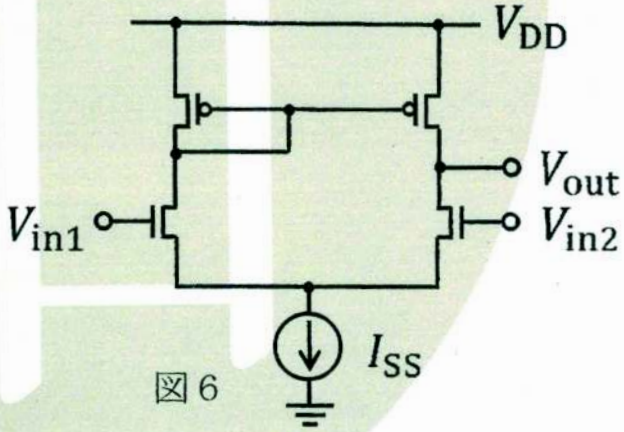


図6

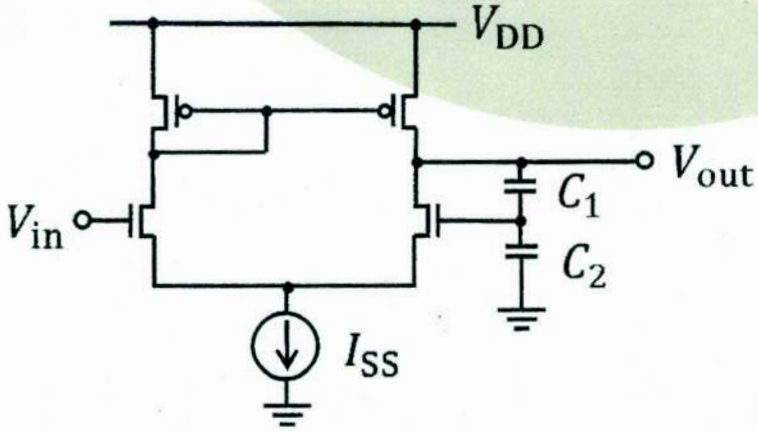
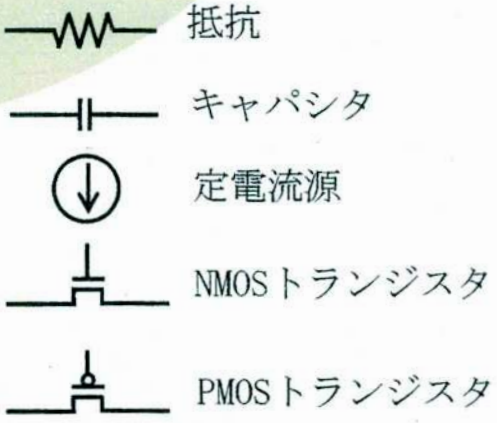


図7



凡例

Problem 2

Because of the non-linear characteristics of MOS transistors, it is difficult to analyze their operation. Therefore, a minute range in the vicinity of the bias point is analyzed. This is referred to as the small-signal analysis method. Figure 1 shows the small-signal model of a short-channel MOS transistor. Here, the substrate bias effect is neglected, and let g_m be the transconductance, r_0 be the output resistance, and v_{gs} be the small signal component of the gate-to-source voltage. Symbols in the figures can be found in the legend. Answer the following questions.

(1) Draw the small-signal equivalent circuit of the common-source circuit with a load resistance R_D as shown in Fig. 2. In addition, express the voltage gain A_V, the input resistance R_{in}, and the output resistance R_{out}.

(2) Figure 3 shows the common-source circuit after replacing R_D in Fig. 2 with a constant current source. Draw the small-signal equivalent circuit for it. In addition, find a formula for the voltage gain A_V.

(3) A constant current source can be realized by a circuit shown in Fig. 4. Draw its small-signal equivalent circuit. In addition, find a formula for the voltage gain A_V.

(4) The circuit shown in Fig. 5 is used to provide a gate bias V_b of the MOS transistor as a constant current source in Fig. 4. In this circuit, the current I_{out} is always equal to I_{in}. Taking this into account, show the differential gain of the differential amplifier circuit shown in Fig. 6.

(5) As shown in Fig. 7, feedback is applied to the differential amplifier circuit by using the capacitors. Find the closed-loop gain of this differential amplifier circuit.

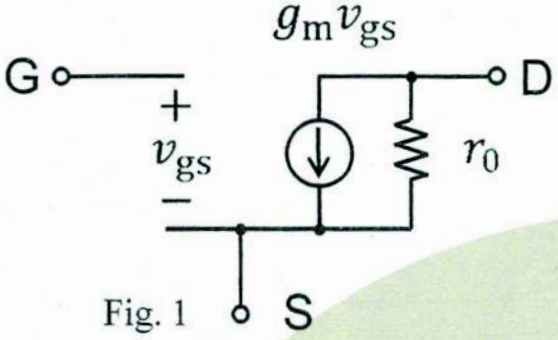


Fig. 1

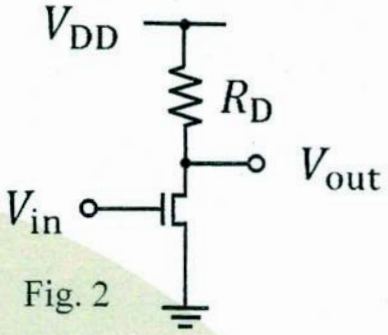


Fig. 2

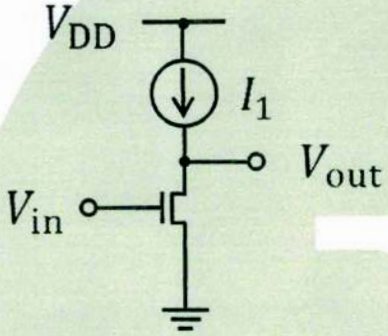


Fig. 3

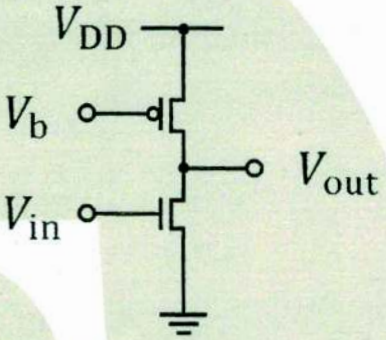


Fig. 4

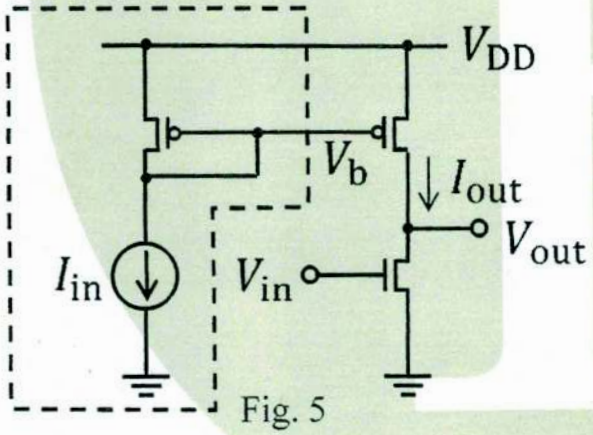


Fig. 5

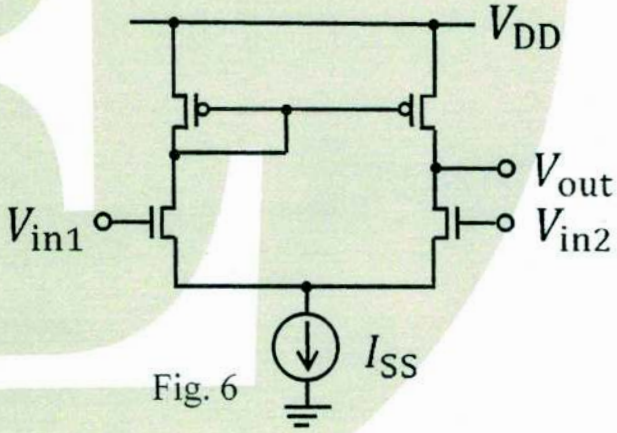


Fig. 6

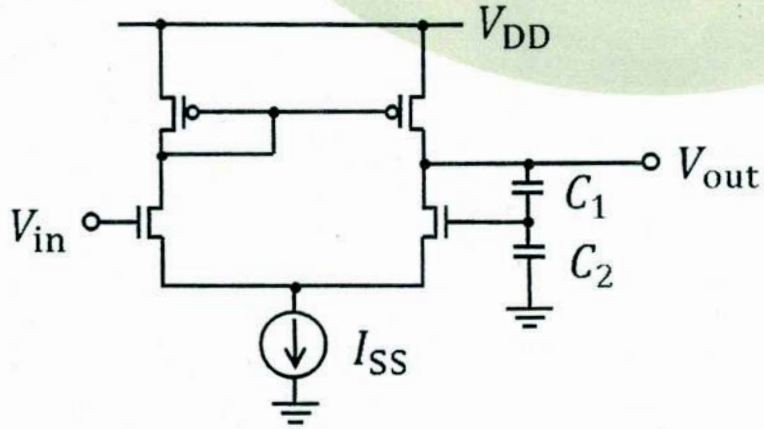
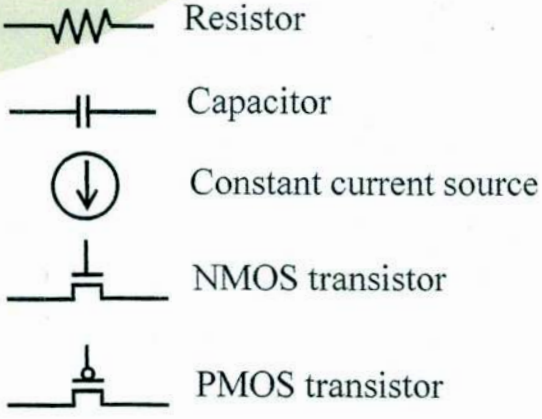


Fig. 7



Legend