**Movie Captions**

**Supplementary Movie S1.** This movie depicts the trajectory of a magnetic bead with ~15.6µm diameter on the transistor illustrated in Figure 3a, when the applied gate current is 35mA. The horizontal and vertical magnetic field components are fixed at 50 Oe, while the in-plane field component rotates clockwise at a driving frequency of 0.1 Hz. The video is presented at 3X speed.

**Supplementary Movie S2.** This movie depicts the trajectory of magnetic beads with ~5.7µm diameter on the transistor illustrated in Figure 3b, when the applied gate current is 0mA (*i.e.*, transistor is off) and 35mA (*i.e.*, transistor is on), for the first and second bead, respectively. The horizontal and vertical magnetic field components are fixed at 50 Oe, while the in-plane field component rotates clockwise at a driving frequency of 0.1 Hz. The video is presented at 3X speed.

**Supplementary Movie S3.** This movie depicts the trajectory of a magnetic beads with ~8.4µm diameter on the transistor illustrated in Figure 3c, when the applied gate current is 45mA. The horizontal and vertical magnetic field components are fixed at 50 Oe, while the in-plane field component rotates counterclockwise at a driving frequency of 0.1 Hz. The video is presented at 2X speed.

**Supplementary Movie S4.** This movie depicts the trajectory of a magnetic beads with ~8.4µm diameter on the transistor illustrated in Figure 3d, when the applied gate current is 40mA. The horizontal and vertical magnetic field components are fixed at 50 Oe, while the in-plane field component rotates counterclockwise at a driving frequency of 0.1 Hz. The video is presented at 2X speed.

**Supplementary Movie S5.** This movie depicts the trajectory of magnetic bead with ~5.7µm diameter on the transistor illustrated in Figure 4a, when the applied gate current is 35mA. The horizontal and vertical magnetic field components are fixed at 50 Oe, while the in-plane field component rotates clockwise at a driving frequency of 0.1 Hz. The video is presented at 3X speed.

**Supplementary Movie S6.** This movie depicts the trajectory of magnetic beads with ~15.6µm diameter on the transistor illustrated in Figure 4b, when the applied gate current is 30mA. The horizontal and vertical magnetic field components are fixed at 50 Oe, while the in-plane field component rotates clockwise at a driving frequency of 0.1 Hz. The video is presented at 2X speed.

**Supplementary Movie S7.** This movie depicts the trajectory of magnetic beads with ~8.4µm diameter on the transistor illustrated in Figure 4c, when the applied gate current is 35mA. The horizontal and vertical magnetic field components are fixed at 50 Oe, while the in-plane field component rotates counterclockwise at a driving frequency of 0.1 Hz. The video is presented at 4X speed.

**Supplementary Movie S8.** This movie depicts the trajectory of magnetic bead with ~15.6µm diameter on the transistor illustrated in Figure 4d, when the applied gate current is 30mA. The horizontal and vertical magnetic field components are fixed at 50 Oe, while the in-plane field component rotates clockwise at a driving frequency of 0.1 Hz. The video is presented at 2X speed.

**Supplementary Movie S9.** This movie depicts the trajectory of magnetically labeled CD4+ T cells on the transistor illustrated in Figure 3b, when the applied gate current is 50mA. The horizontal and vertical magnetic field components are fixed at 50 Oe, while the in-plane field component rotates clockwise at a driving frequency of 0.1 Hz. The video is presented at 1X speed.

**Supplementary Movie S10.** This movie illustrates the trajectory of magnetically labeled CD4+ T cells on the transistor illustrated in Figure 4a, when the applied gate current is 55mA. The horizontal and vertical magnetic field components are fixed at 50 Oe, while the in-plane field component rotates counterclockwise at a driving frequency of 0.1 Hz. The video is presented at 2X speed.

**Supplementary Movie S11.** This movie depicts the trajectory of magnetically labeled CD4+ T cells on the transistor illustrated in Figure 4b (or Figure 6), when the applied gate current is 50mA. The horizontal and vertical magnetic field components are fixed at 50 Oe, while the in-plane field component rotates clockwise at a driving frequency of 0.1 Hz. The video is presented at 1X speed.