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Electronic supplementary information for:

Ubiquitous Magneto-Mechano-Electric Generator

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- Anti-resonance tuning of MME generator.
- Driving of wireless sensor network module by MME generator.

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Video S2: MME harvesting from electric power cable for 7.5 kW vacuum pump.

Video S3: Driving of wireless sensor network module by MME generator under 7 Oe at 60 Hz magnetic field

Video S4: Captured video of wireless sensor monitoring program by MME generator

Table ESI 1. Electro-mechanical properties of piezoelectric single crystal used for ME laminate composites and MME generators

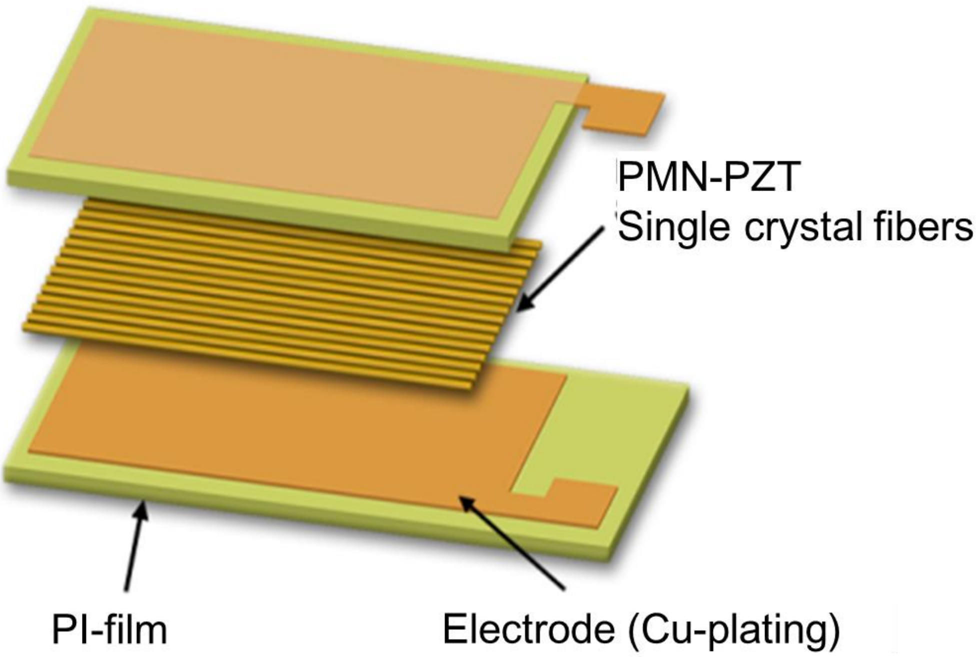
		SSCG CPSC160-95
Density	E+3 [kg/m^3]	7.900
s_{11}^E	E-11 [m^2/N]	6.960
s_{12}^E	E-11 [m^2/N]	-3.307
s_{13}^E	E-11 [m^2/N]	-3.400
s_{33}^E	E-11 [m^2/N]	7.667
s_{44}^E	E-11 [m^2/N]	2.173
s_{66}^E	E-11 [m^2/N]	4.427
d_{15}	E-10 [m^2/N]	2.253
d_{31}	E-10 [m^2/N]	-9.053
d_{33}	E-10 [m^2/N]	20.000
$\varepsilon_{11}^T/\varepsilon_0$	E+3	2.133
$\varepsilon_{33}^T/\varepsilon_0$	E+3	7.200
$\varepsilon_{11}^S/\varepsilon^0$	E+3	1.840
$\varepsilon_{33}^S/\varepsilon^0$	E+3	1.307
Mechanical loss [M]	E-3	10.000
Dielectric loss [D]	E-3	5.000
Piezoelectric loss [P]	E-3	0.000

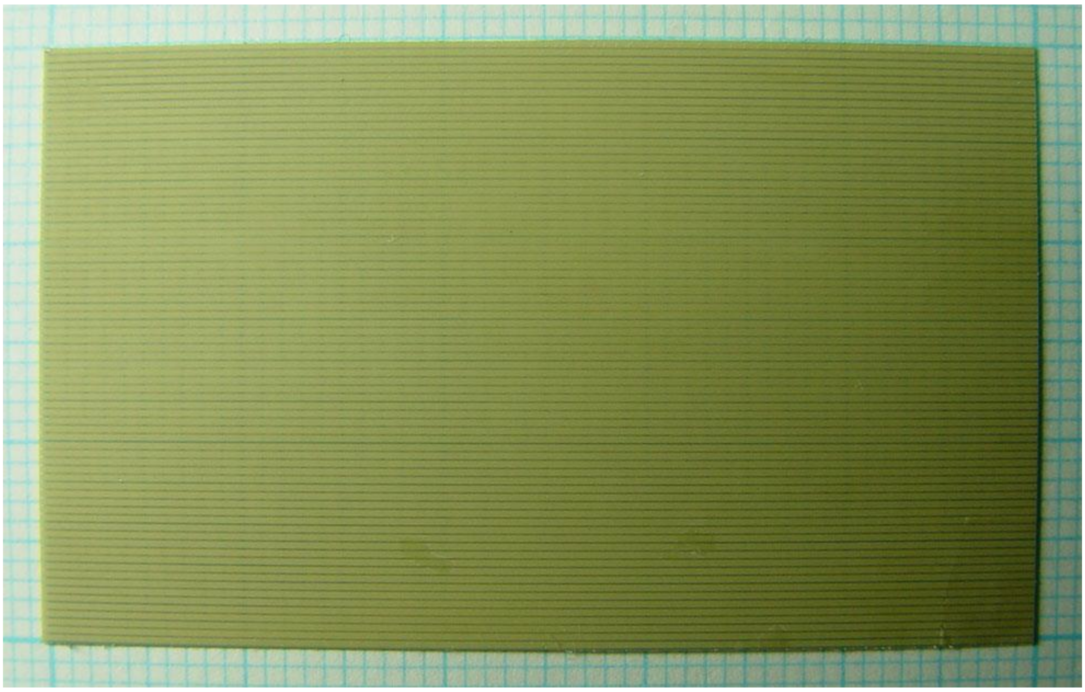
<001> single crystal

		SSCG CPSC160-95
Density	E+3 [kg/m^3]	7.900
s_{11}^E	E-11 [m^2/N]	1.768
s_{12}^E	E-11 [m^2/N]	-3.055
s_{13}^E	E-11 [m^2/N]	0.825
s_{22}^E	E-11 [m^2/N]	11.004
s_{23}^E	E-11 [m^2/N]	-6.081
s_{33}^E	E-11 [m^2/N]	4.875
s_{44}^E	E-11 [m^2/N]	1.466
s_{55}^E	E-11 [m^2/N]	6.818
s_{66}^E	E-11 [m^2/N]	1.281
d_{15}	E-10 [C/N]	11.672
d_{24}	E-10 [C/N]	1.641
d_{31}	E-10 [C/N]	5.993
d_{32}	E-10 [C/N]	-18.500
d_{33}	E-10 [C/N]	10.021
$\varepsilon_{11}^T/\varepsilon_0$	E+3	3.502
$\varepsilon_{22}^T/\varepsilon_0$	E+3	1.107
$\varepsilon_{33}^T/\varepsilon_0$	E+3	3.962
ε_{11}^S	E-9 [F/m]	11.023
ε_{22}^S	E-9 [F/m]	7.967
ε_{33}^S	E-9 [F/m]	2.670
Mechanical loss [M]	E-3	10.000
Dielectric loss [D]	E-3	5.000
Piezoelectric loss [P]	E-3	0.000

<011> single crystal

(a)





(c)

Figure ESI 1. (a) Enlarged schematic illustration of SFC structure, (b) photo of the single crystal fibers before laminating, and (c) magnified photo of (b).

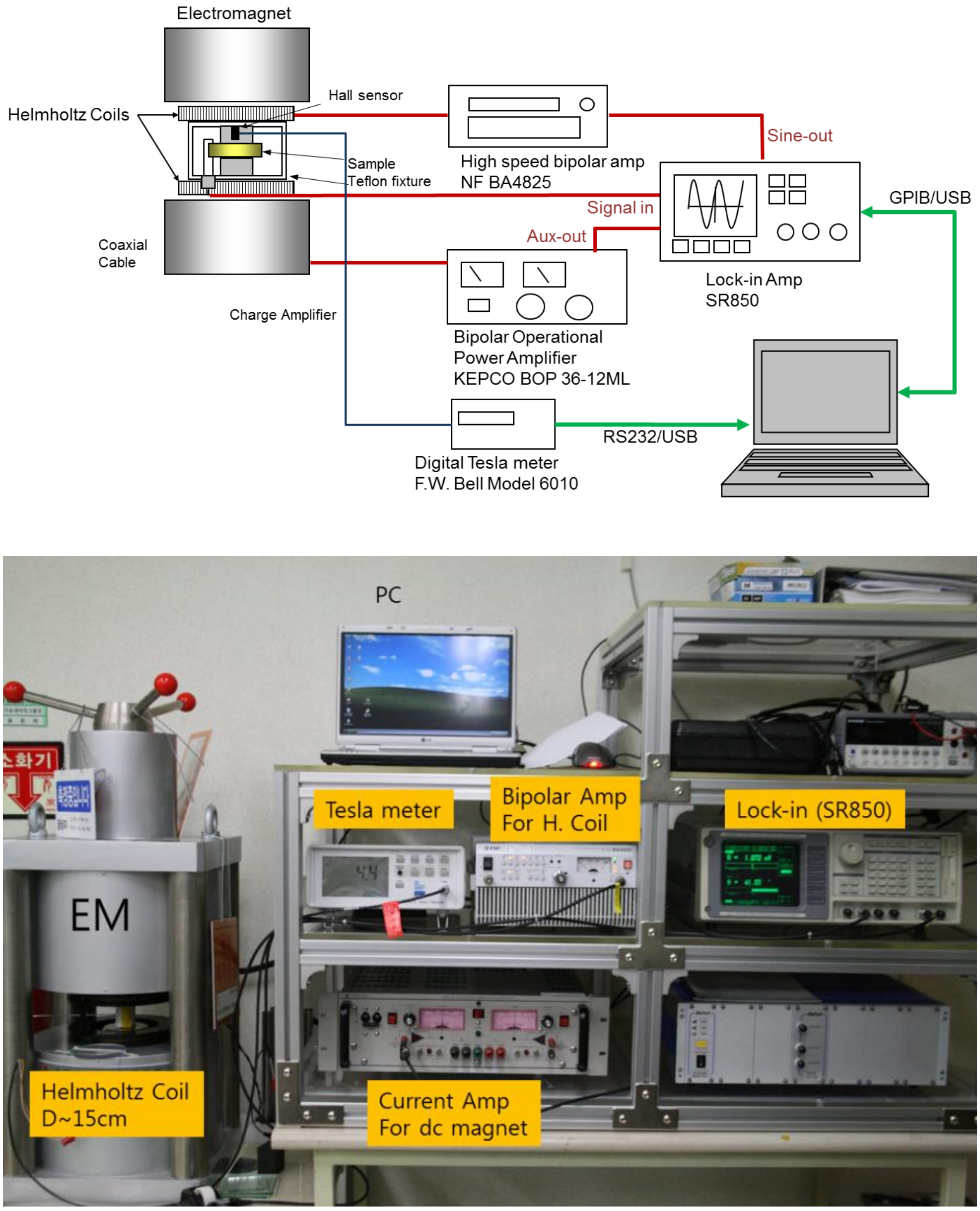


Figure ESI 2. Automated magnetoelectric property measurement system set-up

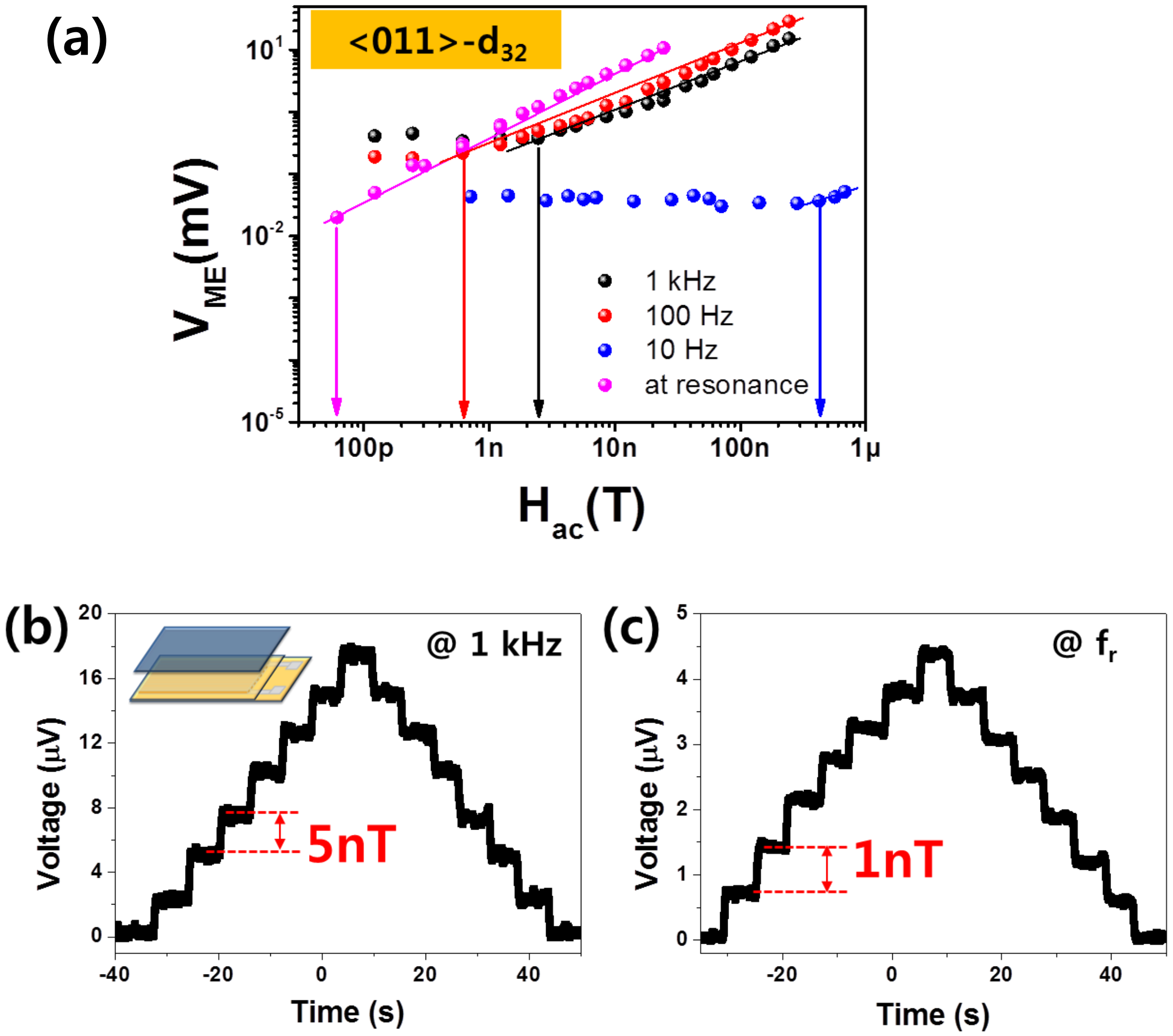


Figure ESI 3. Magnetic field sensitivity of ME laminate composite with anisotropic <011>-d_{32} mode SFC. (a) shows the AC magnetic field sensitivity of the ME laminate composite with anisotropic <011>-d_{32} mode SFC. It showed remarkable AC magnetic field sensitivity (<60 pT) at its resonance mode (~1.7 kHz) without any external DC bias field. Though the sensitivity of the laminate degraded at its off-resonance frequency band, it kept as low as nT range. (b) and (c) represent the time based voltage read with Lock-In amplifier according to the stepped AC magnetic field change. By changing 5 nT and 1 nT at 1 kHz and 1.7 kHz (resonance frequency), ME laminate composite with anisotropic <011>-d_{32} mode SFC generated clear step-like output signal.

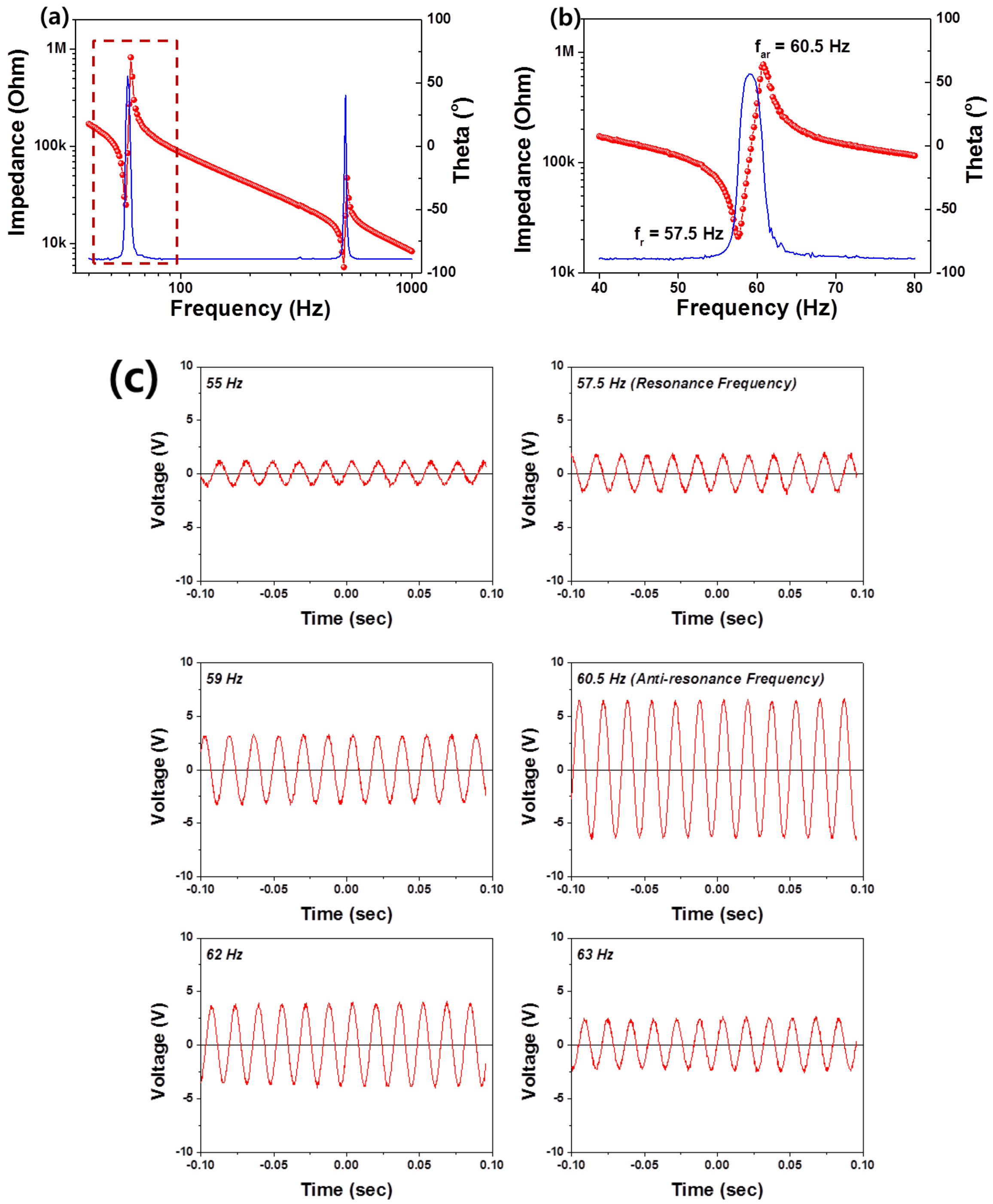


Figure ESI 4. Frequency tuning of MME generator. In one end clamped cantilever structure, the resonance frequencies can be tuned by adjusting the length of the cantilever, weight or position of proof mass. For the MME generator in this study, we fixed other parameters except the position of proof mass. (a) shows electric impedance changes of the frequency tuned MME generator as a function of driving frequency. Two electromechanical resonance peaks were observed at around 60 Hz, and 500 Hz, which correspond to 1^{st} bending and 1^{st} transverse modes, respectively. Since MME generator can draw out maximum voltage at its anti-resonance frequency as shown in (c), anti-resonance frequency of the 1^{st} bending mode was adjusted to ~ 60Hz.

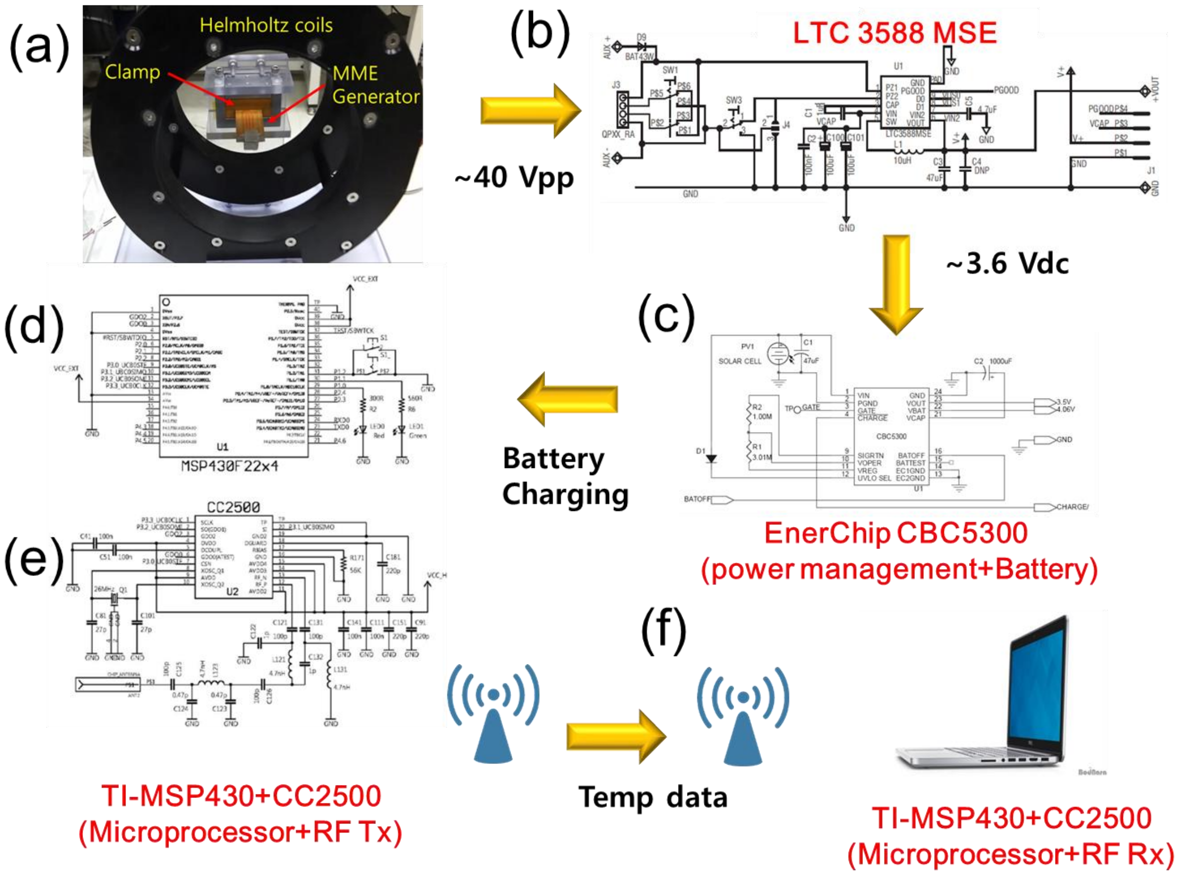


Figure ESI 5. Schematics of driving wireless sensor network module by MME generator. (a) Electric power of ~ 300 μW (~40 Vpp x 30 μA) was generated from 60 Hz, ~ 7 Oe magnetic field inside of Helmholtz coils. (b) Generated power is rectified and regulated by LTC 3588-1 MSE (Nanopower energy harvesting power supply, Linear Technology). The open circuit output voltage after LTC 3588 MSE was ~ 3.6 V_{dc}. (c) The regulated power was transferred and charged to EnerChip EH CBC5300 energy harvesting module (Cymbat Corp.) which has two 50 μAh rechargeable batteries and power management circuit. This module has boost converter to boost the voltage to the voltage needed to charge the battery or power the microprocessor system directly. (d) Charged energy transferred to eZ430-RF2500 module (Texas instruments) which consist of MSP430F2274 microcontroller and (e) CC2500 2.4 GHz wireless transceiver. (f) The integrated temperature sensor in MSP430 microcontroller and RF signal strength indicator were used to monitor the environment and the monitored data were wirelessly transferred to PC by using the same MSP430F2274 and CC2500 RF 2.4 GHz receiver module in every 5 ~ 10 sec. All the detailed information about each circuit modules used in this work can be downloaded from each manufacturers' website.