AB08
N-Channel
FET Characteristics

Operating Manual

Ver.1.1

An ISO 9001 : 2000 company

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RoHS Compliance

Scientech Products are RoHS Complied.

RoHS Directive concerns with the restrictive use of Hazardous substances (Pb, Cd, Cr, Hg, Br compounds) in electric and electronic equipments.

Scientech products are "Lead Free" and "Environment Friendly".

It is mandatory that service engineers use lead free solder wire and use the soldering irons upto (25 W) that reach a temperature of 450°C at the tip as the melting temperature of the unleaded solder is higher than the leaded solder.

Introduction

AB08 is a compact, ready to use **FET Characteristics** experiment board. This is useful for students to plot different characteristics of an N channel Field Effect Transistor and to understand operation of an FET in different regions. It can be used as stand alone unit with external DC power supply or can be used with **Scientech Analog Lab ST2612** which has built in DC power supply, AC power supply, function generator, modulation generator, continuity tester, toggle switches, and potentiometer.

List of Boards :

Model	Name
AB01	Diode characteristics (Si, Zener, LED)
AB02	Transistor characteristics (CB NPN)
AB03	Transistor characteristics (CB PNP)
AB04	Transistor characteristics (CE NPN)
AB05	Transistor characteristics (CE PNP)
AB06	Transistor characteristics (CC NPN)
AB07	Transistor characteristics (CC PNP)
AB09	Rectifier Circuits
AB10	Wheatstone bridge
AB11	Maxwell’s Bridge
AB12	De Sauty’s Bridge
AB13	Schering Bridge
AB14	Darlington Pair
AB15	Common Emitter Amplifier
AB16	Common Collector Amplifier
AB17	Common Base Amplifier
AB18	RC-Coupled Amplifier
AB19	Cascode Amplifier
AB20	Direct Coupled Amplifier
AB21	Class A Amplifier
AB22	Class B Amplifier (push pull emitter follower)
AB23	Class C Tuned Amplifier
AB24	Transformer Coupled Amplifier
AB25	Phase Locked Loop (FM Demodulator & Frequency Divider / Multiplier)
AB26	FET Amplifier
AB27	Voltage Controlled Oscillator
AB28	Multivibrator (Monostable / Astable)
AB29	F-V and V-F Converter
AB30	V-I and I-V Converter
AB31	Zener Voltage Regulator
AB32	Transistor Series Voltage Regulator
AB33	Transistor Shunt Voltage Regulator
AB35	DC Ammeter
AB37	DC Ammeter (0-2mA)
AB39	Instrumentation Amplifier

AB41	Differential Amplifier (Transistorized)
AB42	Operational Amplifier (Inverting / Non-inverting / Differentiator)
AB43	Operational Amplifier (Adder/Scalar)
AB44	Operational Amplifier (Integrator/ Differentiator)
AB45	Schmitt Trigger and Comparator
AB49	K Derived Filter
AB51	Active filters (Low Pass and High Pass)
AB52	Active Band Pass Filter
AB54	Tschebyscheff Filter
AB56	Fiber Optic Analog Link
AB57	Owen’s Bridge
AB58	Anderson’s Bridge
AB59	Maxwell’s Inductance Bridge
AB64	RC – Coupled Amplifier with Feedback
AB66	Wien Bridge Oscillators
AB67	Colpitt Oscillator
AB68	Hartley Oscillator
AB80	RLC Series and RLC Parallel Resonance
AB82	Thevenin’s and Maximum Power Transfer Theorem
AB83	Reciprocity and Superposition Theorem
AB84	Tellegen’s Theorem
AB85	Norton’s theorem
AB88	Diode Clipper
AB89	Diode Clampers
AB90	Two port network parameter
AB91	Optical Transducer (Photovoltaic cell)
AB92	Optical Transducer (Photoconductive cell/LDR)
AB93	Optical Transducer (Phototransistor)
AB96	Temperature Transducer (RTD & IC335)
AB97	Temperature Transducer (Thermocouple)
AB101	DSB Modulator and Demodulator
AB102	SSB Modulator and Demodulator
AB106	FM Modulator and Demodulator

and many more…………

Theory

FET is a voltage controlled current device so its characteristics are the curves which represent relationship between different DC currents and voltages. These are helpful in studying different region of operation of a Field effect transistor when connected in a circuit. The two important characteristics of a Field Effect Transistor are:

1. Output /Drain characteristic.

2. Transfer characteristic.

Output / Drain Characteristics :

It is the curve plotted between output drain current I_D versus output drain to source voltage V_{DS} for constant values of input Gate to source voltage V_{GS} as shown in figure 1.

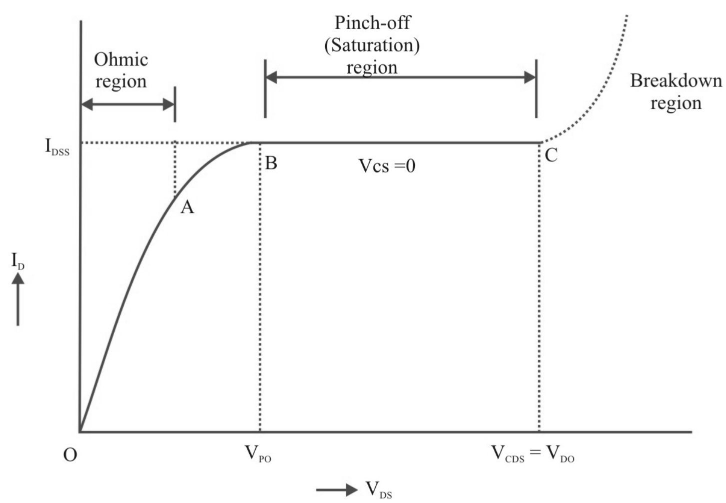


Figure 1

It can be subdivided into following four regions:

Ohmic region OA :

This part of the characteristic is linear indicating that for low values of V_{DS}, current varies directly with voltage following Ohm's Law. It means that JFET behaves like an ordinary resistor till point A (called knee) is reached.

Curve AB :

In this region, I_D increases at inverse square law rate upto point B which is called Pinch-off point. This progressive fall in the rate of increase of I_D is caused by the square law increase in the depletion region at each gate up to point B where the two regions are closest without touching each other. The drain to source voltage V_{DS} corresponding to point B is called pinch-off voltage V_{PO}.

Pinch-off region BC :

It is also known as saturation region or 'amplifier' region. Here, JFET operates as a constant-current device because I_D is relatively independent of V_{DS}. It is due to the fact that as V_{DS} increases channel resistance also increases proportionally thereby keeping I_D practically constant at I_{DSS}.
Drain current in this region is given by Shockley's equation

It is the normal operating region of the JFET when used as an amplifier.

$$I_D = I_{DSS} [1 - (V_{GS} / V_{PO})^2] = I_{DSS} [- (V_{GS} / V_{GS\ (off)})^2]$$

Breakdown region :

If V_{DS} is increased beyond its value corresponding to point C (called avalanche breakdown voltage), JFET enters the breakdown region where I_D increases to an extensive value. This happens because the reversed biased gate channel PN junction undergoes avalanche breakdown when small change in V_{DS} produce very large change in I_D.

JFET characteristics with External Bias :

Figure 2 shows a family of I_D versus V_{DS} curves for different values of V_{GS}. It is seen that as the negative gate bias voltage is increased:
Pinch-off voltage V_P is reached at a lower value of V_{DS} than V_{GS} = 0. Value of V_{DS} for breakdown is decreased.

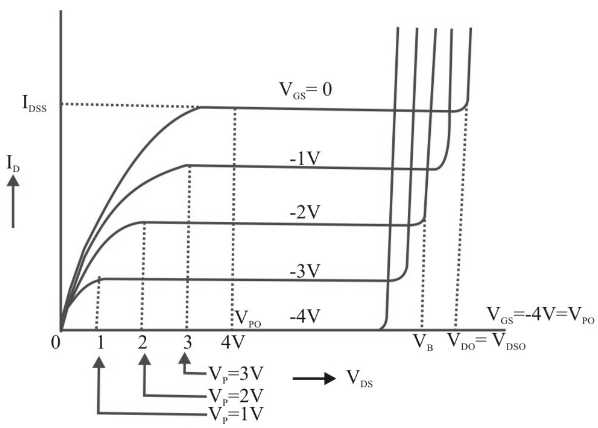


Figure 2

Transfer Characteristic :

It is the curve plotted between output drain current versus input Gate to source voltage for constant values of output drain to source voltage as shown in figure 3.

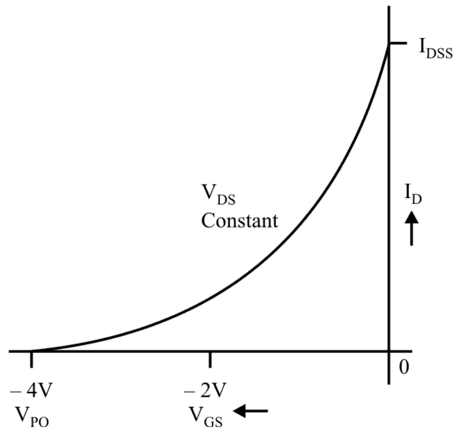


Figure 3

It is similar to the transconductance characteristics of a vacuum tube or a transistor. It shows that when $V_{GS} = 0$, $I_D = I_{DSS}$ and when $I_D = 0$, $V_{GS} = V_{PO}$. The transfer characteristic approximately follows the equation

$$I_D = I_{DSS}\,[1 - (V_{GS} / V_{PO})^2\,] = I_{DSS}\,[\,1 - (V_{GS} / V_{GS(off)})^2\,]$$

The above equation can be written as $V_{GS} = V_{GS\ (off)}\ [1 - (I_D / I_{DSS})^{1/2}\ ]$ These characteristics can also be obtained from the drain/output characteristics by reading off V_{GS} and I_{DSS} values for different values of V_{DS}.

The various parameters of a JFET can be obtained from its two characteristics.

The main parameters of a JFET when connected in common source mode are

AC Drain Resistance, r_d :

It is the AC resistance between drain and source terminals when JFET is operating in the pinch-off region. It is given by

$$r_d = \frac{\text{change in } V_{DS}}{\text{change in } I_D} \quad \text{at } V_{GS} \text{ constant or } r_d = V_{DS} / I_D \,|\, V_{GS}$$

An alternative name is dynamic drain resistance. It is given by the slope of the drain characteristics in the pinch off region. It is sometimes written as r_{ds} emphasizing the fact that it is the resistance from drain to source. Since r_d is usually the output resistance of a JFET, it may also be expressed as an output admittance y_{os}. Obviously, $y_{os} = 1/r_d$. It has a very high value.

Transconductance, g_m :

It is simply the slope of transfer characteristics

$$g_m = \frac{\text{change in } I_D}{\text{change in } V_{GS}} \quad \text{at } V_{DS} \text{ constant or } r_d = I_D / V_{GS} \mid V_{DS}$$

Its unit is siemens (S) /Mho. It is also called forward transconductance (g_{fs}) or forward transadmittance Y_{fs}. The transconductance measured at I_{DSS} is written as g_{mo}.

Mathematically

$$g_m = g_{mo} [1 - (V_{GS} / V_P)]$$

Amplification factor, m :

It is given by

$$\mu = \frac{\text{change in } V_{DS}}{\text{change in } V_{GS}} \quad \text{at } I_D \text{ constant or } \mu = V_{DS} / V_{GS} \mid I_{DS}$$

It can be proved from above that $\mu = g_m \times r_d = g_{fs} \times r_d$

DC drain resistance, R_{DS} :

It is also called the static or ohmic resistance of the channel. It is given by

$$R_{DS} = V_{DS} / I_D$$

Experiment

Objective :

Study of the characteristics of JFET (Junction field effect transistor) in common source configuration and evaluation of:

1. **AC drain resistance**
2. **Transconductance**
3. **Amplification factor**
4. **Drain Resistance**

Equipments Needed :

1. Analog board of **AB08.**
2. DC power supplies +12V,-5V from external source or **ST2612 Analog Lab**.
3. Digital Multimeter (3 numbers).
4. 2 mm patch cords.

Circuit diagram :

Circuit used to plot different characteristics of transistor is shown in figure 4.

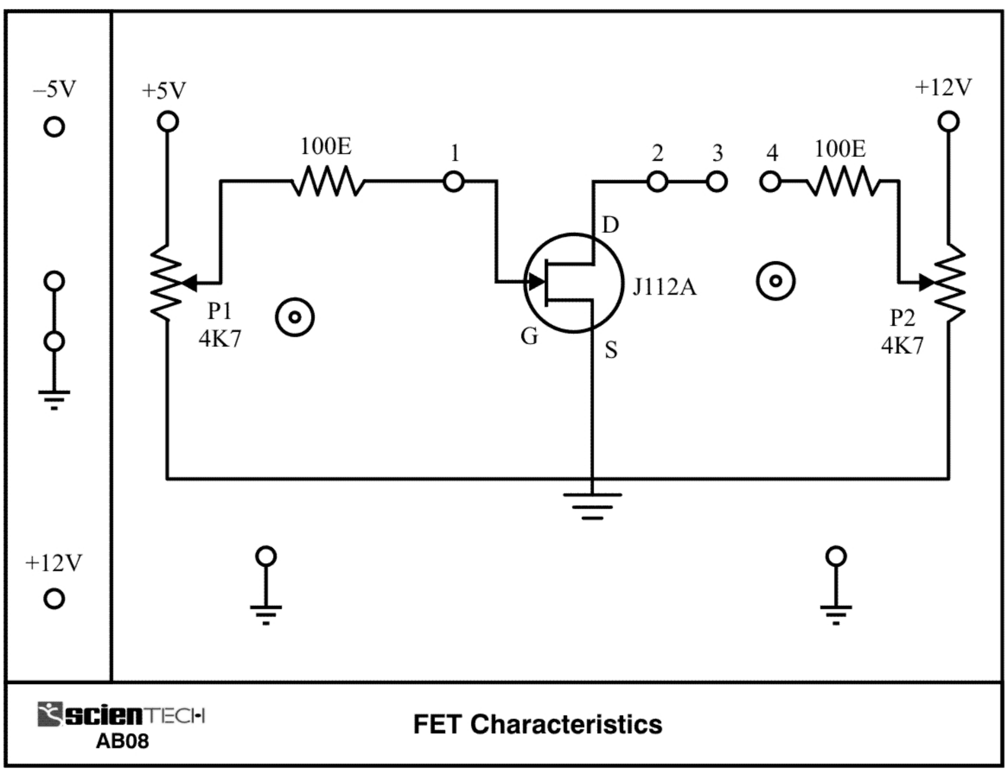


Figure 4

Procedure :

1. Connect -5V and + 12V DC power supplies at there indicated position from external source or **ST2612 Analog Lab**.

2. To plot Drain characteristics proceed as follows :

3. Rotate both the potentiometer P_1 and P_2 fully in counter clockwise direction.

4. Connect Ammeter between test point 3 and 4 to measure output drain current I_D (mA).

5. Connect one voltmeter between test point 1 and ground to measure input voltage V_{GS} other voltmeter between test point 2 and ground to measure output voltage V_{DS}.

6. Switch 'On' the power supply.

7. Vary the potentiometer P_2 so as to increase the value of output voltage V_{DS} from zero to 10V in step and measure the corresponding values of output drain current I_D for different constant value of output voltage V_{DS} in an observation table 1.

8. Rotate potentiometer P_2 fully in Counter Clockwise direction.

9. Rotate potentiometer P_1 and set the value of input gate to source voltage at some constant value (-1V, -2V, -3V……….)

10. Repeat the procedure from step 6 for different sets of input voltage V_{GS}.

11. Plot a curve between output voltage V_{DS} and output current I_D at different constant values of input gate to source voltage as shown in figure 2 using suitable scale with the help of observation table 1. This curve is the required output/Drain characteristic.

Observation Table 1 :

S. no.	Output voltage V_{DS} (volt)	Output Drain current I_D (mA) at constant Value of input voltage			
		$V_{GS} = 0V$	$V_{GS} = -1V$	$V_{GS} = -2V$	$V_{GS} = -3V$
1.	0.0V				
2.	1.0V				
3.	2.0V				
4.	3.0V				
5.	4.0V				
6.	5.0V				
7.	6.0V				
8.	7.0V				
9.	8.0V				
10.	9.0V				

1. To plot Transfer characteristics proceed as follows :

2. Switch 'Off' the power supply.

3. Rotate both the potentiometer P_1 and P_2 fully in Counter Clockwise (counter clockwise direction).

4. Connect voltmeter between test point 6 and ground to measure output voltage V_{DS}.

5. Connect one Ammeter between test point 3 and 4 to measure output current I_D(mA)

6. Vary potentiometer P_2 and set a value of output voltage V_{DS} at some constant value (1 V, 2V, 3V..........)

7. Vary the potentiometer P_1 so as to increase the value of input voltage V_{GS} from zero to maximum value in step and measure the corresponding values of output current I_D in an observation table 2

8. Rotate potentiometer P_1 fully in Counter Clockwise direction.

9. Repeat the procedure from step 5 for different sets of output voltage V_{DS}.

10. Plot a curve between input voltage V_{GS} and output current I_D as shown in Figure 3 using suitable scale with the help of observation table 2. This curve is the required Transfer characteristic.

Observation Table 2 :

S. No.	Input voltage V_{GS} (volt)	Output Drain current I_D (mA) at constant value of input voltage				
		V_{DS} = 1V	V_{DS} = 2V	V_{DS} = 3V	V_{DS} = 4V	V_{DS} = 5V
1.	0.0V					
2.	-0.5V					
3.	-1.0V					
4.	-1.5V					
5.	-2.0V					
6.	-2.5V					
7.	-3.0V					
8.	-3.5V					
9.	-4.0V					

Calculations :

AC Drain Resistance, r_d :

It is the AC resistance between drain and source terminals when JFET is operating in the pinch-off region. To calculate AC drain resistance calculate the slope of the drain characteristics in the pinch off region obtained from Observation Table 1.

$$r_d = \frac{\text{change in } V_{DS}}{\text{change in } I_D} \quad \text{at } V_{GS} \text{ constant or } r_d = V_{DS} / I_D \,|\, V_{GS}$$

It has a very high value.

Transconductance, g_m :

To calculate transconductance determine slope of the transfer characteristics obtained from Observation Table 2

$$g_m = \frac{\text{change in } I_D}{\text{change in } V_{GS}} \quad \text{at } V_{DS} \text{ constant or } r_d = I_D / V_{GS} \,|\, V_{DS}$$

Its unit is siemens (S) / mho.

Amplification factor, m :

It is given by

$$\mu = \frac{\text{change in } V_{DS}}{\text{change in } V_{GS}} \quad \text{at } I_D \text{ constant or } \mu = V_{DS} / V_{GS} \,|\, I_{DS}$$

or $\mu = g_m * r_d$

DC drain resistance, R_{DS} :

It is also called the static or ohmic resistance of the channel. It is given by

$$R_{DS} = V_{DS} / I_D$$

Results :

AC

Drain Resistance r_d = __________

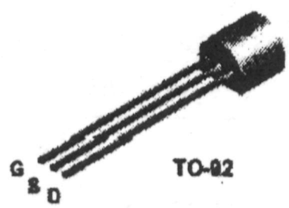
Transconductance, g_m = ________

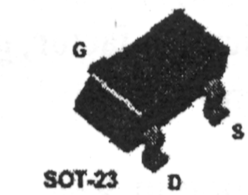
Amplification factor μ = ________

DC drain resistance, R_{DS} ___________=

Data Sheet

J111 J112 J113 / MMBFJ111 MMBFJ112 MMBFJ113





Mark: 6P / 6R / 6S

NOTE: Source & Drain are interchangeable

N-Channel Switch

This device is designed for low level analog switching, sample and hold circuits and chopper stabilized amplifiers. Sourced from Process 51.

Absolute Maximum Ratings* TA = 25°C unless otherwise noted

Symbol	Parameter	Value	Units
V_{DG}	Drain-Gate Voltage	35	V
V_{GS}	Gate-Source Voltage	- 35	V
I_{GF}	Forward Gate Current	50	mA
T_J, T_{stg}	Operating and Storage Junction Temperature Range	-55 to +150	°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

NOTES:
1) These ratings are based on a maximum junction temperature of 150 degrees C.
2) These are steady state limits. The factory should be consulted on applications involving pulsed or low duty cycle operations.

Thermal Characteristics TA = 25°C unless otherwise noted

Symbol	Characteristic	Max		Units
		J111-113	*MMBFJ111-113	
P_D	Total Device Dissipation Derate above 25°C	625 5.0	350 2.8	mW mW/°C
$R_{\theta JC}$	Thermal Resistance, Junction to Case	125		°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	357	556	°C/W

*Device mounted on FR-4 PCB 1.6" X 1.6" X 0.06."

Electrical Characteristics

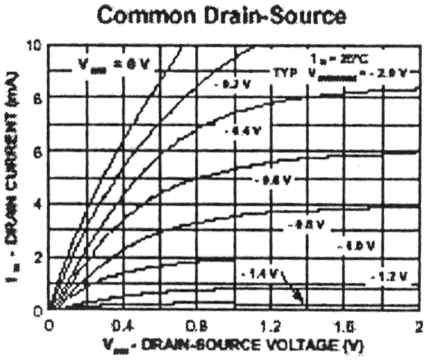
TA = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions		Min	Max	Units
OFF CHARACTERISTICS						
$V_{(BR)GSS}$	Gate-Source Breakdown Voltage	I_G = - 1.0 μA, V_{DS} = 0		- 35		V
I_{GSS}	Gate Reverse Current	V_{GS} = - 15 V, V_{DS} = 0			- 1.0	nA
$V_{GS(off)}$	Gate-Source Cutoff Voltage	V_{DS} = 5.0 V, I_D = 1.0 μA	111 112 113	- 3.0 - 1.0 - 0.5	- 10 - 5.0 - 3.0	V V V
$I_{D(off)}$	Drain Cutoff Leakage Current	V_{DS} = 5.0 V, V_{GS} = - 10 V			1.0	nA
ON CHARACTERISTICS						
I_{DSS}	Zero-Gate Voltage Drain Current*	V_{DS} = 15 V, I_{GS} = 0	111 112 113	20 5.0 2.0		mA mA mA
$r_{DS(on)}$	Drain-Source On Resistance	V_{DS} ≤ 0.1 V, V_{GS} = 0	111 112 113		30 50 100	Ω Ω Ω
SMALL-SIGNAL CHARACTERISTICS						
$C_{dg(on)}$ $C_{sg(on)}$	Drain Gate & Source Gate On Capacitance	V_{DS} = 0, V_{GS} = 0, f = 1.0 MHz			28	pF
$C_{dg(off)}$	Drain-Gate Off Capacitance	V_{DS} = 0, V_{GS} = - 10 V, f = 1.0 MHz			5.0	pF
$C_{sg(off)}$	Source-Gate Off Capacitance	V_{DS} = 0, V_{GS} = - 10 V, f = 1.0 MHz			5.0	pF

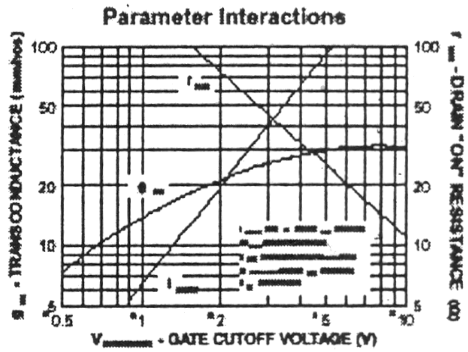
*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 3.0%

Typical Characteristics

Common Drain-Source



Parameter Interactions



Warranty

1. We guarantee the product against all manufacturing defects for 24 months from the date of sale by us or through our dealers. Consumables like dry cell etc. are not covered under warranty.
2. The guarantee will become void, if
   a) The product is not operated as per the instruction given in the operating manual.
   b) The agreed payment terms and other conditions of sale are not followed.
   c) The customer resells the instrument to another party.
   d) Any attempt is made to service and modify the instrument.
3. The non-working of the product is to be communicated to us immediately giving full details of the complaints and defects noticed specifically mentioning the type, serial number of the product and date of purchase etc.
4. The repair work will be carried out, provided the product is dispatched securely packed and insured. The transportation charges shall be borne by the customer.

For any Technical Problem Please Contact us at **service@scientech.bz**

List of Accessories

1. 2 mm Patch Cords (Red) .... 2 Nos.
2. 2 mm Patch Cord (Black) .... 2 Nos.
3. 2 mm Patch Cord (Blue) .... 1 No.
4. e-Manual .... 1 No.

Updated 08-01-2009