INTEGRATED RESOURCES, INCORPORATED

TECHNICAL REPORT

COVER SHEET

IRI PROJECT NUMBER: CEI-9502 AND NIMO-9502

CLIENT PROJECT NUMBER: S 137501 AND 95-06135

CLIENT: CLEVELAND ELECTRIC ILUMINATING AND NIAGARA MOHAWK POWER CORPORATION

PROJECT TITLE: G. E. MODEL 169C8805P002 POWER SUPPLY REFURBISHMENT AND SALE.

DOCUMENT TITLE: EVALUATION AND ANALYSIS OF G. E. MODEL 169C8805P002/KEPCO, INC., RMX 24-D-20804 POWER SUPPLIES.

DOCUMENT TOTAL PAGES (EXCLUDING COVER SHEET): 8

TECHNICAL REPORT NUMBER: CEI-9502-01/NIMO-9502-01

REVISION: 1

ORIGINATOR: John F Broemer DATE: 4/26/95

EXECUTIVE SUMMARY

This report provides final recommendations and the pertinent data obtained during testing and evaluations for the refurbishment and repair of KEPCO, Inc. Model RMX 24-D-20804 Power Supplies.

Integrated Resources, Inc., (IRI) observed that "SAFETY RELATED" power supplies provided by two customers for refurbishment had failed in exactly the same manner. During discussions with KEPCO, Inc., the original equipment manufacturer, IRI was advised that transistors Q15 and Q16 were "marginal". Based on KEPCO's analysis IRI reported a possible design deficiency as required by IRI's QA Program and 10 CFR 21 to the U. S. Nuclear Regulatory Commission verbally on 3/24/95 and in writing on 3/27/95.

Since the notifications Integrated Resources, Inc., has selected a replacement transistor XSIS-095 and thoroughly tested the Kepco, Inc., Model RMX 24-D-20804 power supplies with the replacement transistors installed. Integrated Resources, Inc., believes that replacement of Q15 and Q16 with XSIS-095 when coupled with replacement of the aluminum electrolytic capacitors provides a long term solution to the original problems associated with these power supplies.

Integrated Resources, Inc., with Kepco, Inc.'s concurrence recommends that transistors Q15 and Q16 be replaced with XSIS-095 and that all age related aluminum electrolytic capacitors be replaced on all Kepco, Inc., RMX 24-D-20804 power supplies which are returned for refurbishment.

Integrated Resources, Inc., additionally recommends that each individual nuclear facility with KEPCO, Inc., RMX 24-D-20804 power supplies installed evaluate the systems and usage of the power supplies and based on the power supplies criticality to the systems operability determine whether the individual power supplies should be refurbished.

INTRODUCTION

Integrated Resources, Inc., (IRI) observed that two different customers had sent us power supplies in which Q15 and/or Q16 had failed open and R1 (soft start bypass resistor) was open. One unit from Niagara Mohawk Power Corporation, Nine Mile Point Unit 2, and 3 units from Cleveland Electric Illuminating, Perry Nuclear Power Plant. Subsequently, during AS FOUND testing 3 Perry units failed in exactly the same manner. This led to an order being placed to KEPCO, Inc. for replacement transistors. The replacement transistors supplied by Kepco, Inc. were 2SD380's rather than the 2SC2507 transistors specified by the parts list, and therefore, were rejected during receipt inspection. IRI contacted Kepco, Inc. believing that Kepco had supplied these transistors as substitutes for an obsolete device. IRI requested that Kepco, Inc., supply IRI with the substitute transistor information and the information on the power supply circuit analysis which would allow IRI to dedicate the replacement parts. Kepco, Inc. called back indicating that their preliminary analysis indicated that the transistors could see 428 V and 3.5 A maximum in the power supply circuitry.

At this point IRI pointed out that the transistors were 400 V devices. and that it was possible that the output transistors were being operated at voltages above their design specification. Kepco, Inc., indicated that their had been some problems with these transistors and their replacements all of the way back to the power supply production period. IRI explained that the power supplies were used in some "SAFETY RELATED" applications at nuclear power plants and that if the preliminary analysis were proven correct that we must issue a 10 CFR 21 notification for the defective part(s). The Kepco, Inc. engineer requested 24 hours to allow further analyses and a complete review of his calculations.

The following day, the engineer called and indicated that his preliminary investigations were proven correct by his Chief Engineer and that the notification was required.

It was later discovered that there was a typographical error in the RMX 24-D-20804 Technical Manual, which caused IRI to order Kepco, Inc., part number 519-0036 (2SD380) rather than the 519-0037 (2SC2507).

EVALUATION AND ANALYSIS

Since issuing the 10 CFR 21 Notification, on 3/27/95 Integrated Resources, Inc. with immense amounts of technical assistance and analyses from Kepco, Inc. has analyzed the Kepco, Inc. RMX 24-D-20804 power supply with the following results:

1. Transistors Q15 and Q16 were initially specified to be T20M40 manufactured by Shindengen.

   We can find no reference for a standard part number T20M40, however, a T20M40F3 was manufactured by Shindengen. This transistor had the following specifications:

   I_C = DC Collector Current, Rated Maximum = 20 A.
   $V_{(BR)CEO}$ = Breakdown Voltage, Collector-to-Emitter with Base Open = 400 V.
   h_{FE} = Static Forward Current Transfer Ratio, Common-Emitter = 10 Minimum
   P_D = Power Dissipation, Rated Maximum = 200 W.
   Package Style = TO-204

2. According to Kepco, Inc., records when T20M40 transistors were taken out of production, TDK specified a substitute transistor manufactured by Shindengen, a 2SC2507. This transistor has the following specifications:

   I_C = DC Collector Current, Rated Maximum = 20 A.
   $V_{(BR)CEO}$ = Breakdown Voltage, Collector-to-Emitter with Base Open = 400 V.
   h_{FE} = Static Forward Current Transfer Ratio, Common-Emitter = 15 Minimum, 20 Maximum
   P_D = Power Dissipation, Rated Maximum = 200 W.
   Package Style = TO-3

3. According to Kepco, Inc., records when the 2SC2507 transistors were taken out of production, TDK specified a substitute transistor, 2SC2930-06 manufactured by Fuji Electric Co., Ltd. The specifications for the generic 2SC2930 transistor are as follows:

   I_C = DC Collector Current, Rated Maximum = 30 A.
   $V_{(BR)CEO}$ = Breakdown Voltage, Collector-to-Emitter with Base Open = 400 V.
   h_{FE} = Static Forward Current Transfer Ratio, Common-Emitter = 15 Minimum
   P_D = Power Dissipation, Rated Maximum = 200 W.
   Package Style = TO-3

Transistor 2SC2930-06 specifications are as follows:

I_C = DC Collector Current, Rated Maximum = 20 A.
$V_{(BR)CEO}$ = Breakdown Voltage, Collector-to-Emitter with Base Open = 400 V.
h_{FE} = Static Forward Current Transfer Ratio, Common-Emitter = 22 Minimum
P_D = Power Dissipation, Rated Maximum = 200 W.
Package Style = TO-3

As can be seen during the entire production period of this power supply Q15 and Q16 have been specified with transistors which have a $V_{(BR)CEO}$ (Breakdown Voltage, Collector-to-Emitter with Base Open) of 400 V. Kepco, Inc. has calculated that these transistors as used in this application can see voltages as high as 428 V. Thus during the entire production period the power supplies were produced using "marginal" output transistors, Q15 and Q16.

It is also believed that these problems are compounded as capacitors C4, C5, C6, C7, C8 and C9 age. These capacitors are aluminum electrolytic capacitors which have a shelf/useful life.

Aluminum electrolytic capacitors age during storage and/or operation. The aging effect is caused by the gradual loss of the capacitor's electrolyte by vapor transmission through the end seal. The expected shelf/useful life of the capacitor is directly dependent on the loss of electrolyte, which is dependent on the composition of the electrolyte, the effectiveness of the end seal, and the operating and or storage temperatures.

The effect of the loss of electrolyte initially has little effect on the electrical performance of the capacitors. However, after about 40% of the electrolyte is lost, the Equivalent Series Resistance (ESR) increases rapidly, capacitance decreases and ultimately the capacitors appear open.

Since the capacitors are installed in different areas of the power supply and therefore, operate under slightly different operating temperatures and since the capacitors themselves tend to "age" at slightly different rates, the true operating voltages impressed across Q15 and/or Q16 over the life of the power supply will vary. If the capacitors age at different rates and the capacitors control the voltage across Q15 and Q16, then the voltage across Q15 and Q16 vary in accordance with the rate of aging of the capacitors. If the capacitors continue to age differentially it is possible that the voltage across one of the transistors will increase to the point of failure of an already marginal transistor.

In order to correct the "marginal" transistor problem, Integrated Resources, Inc., selected two different transistors with as similar as possible specifications but with a $V_{(BR)CEO} \geq 500$ V. as possible candidates for replacement of Q15 and Q16. These transistors bear IRI part numbers XSIS-094 and XSIS-095. The transistor specifications are as follows:

XSIS-094

I_C = DC Collector Current, Rated Maximum = 20 A.
$V_{(BR)CEO}$ = Breakdown Voltage, Collector-to-Emitter with Base Open = 500 V.
h_{FE} = Static Forward Current Transfer Ratio, Common-Emitter = 15 Minimum, 75 Maximum
P_D = Power Dissipation, Rated Maximum = 175 W.
Package Style = TO-3

XSIS-095

I_C = DC Collector Current, Rated Maximum = 20 A.
$V_{(BR)CEO}$ = Breakdown Voltage, Collector-to-Emitter with Base Open = 500 V.
h_{FE} = Static Forward Current Transfer Ratio, Common-Emitter = 40 Minimum
P_D = Power Dissipation, Rated Maximum = 175 W.
Package Style = TO-3

TESTING

Integrated Resources, Inc., refurbished two power supplies replacing all aluminum electrolytic capacitors and placed XSIS-094 output transistors in one power supply and XSIS-095 output transistors in the second supply. Both units were placed into burn in and the testing commenced. During the initial phase of the burn in test the units were set for a constant voltage output of 26.4 VDC (100% rated) and cycled through the entire range of output amperage. Temperature of 9 points on the heat sink and both output transistor temperatures were measured at 2, 5, 12 and 15 Amp outputs. All temperatures taken during this test are conservative since all 4 side panels of the power supply were removed, which results in all heat generated by the components mounted to the heat sink having only the heat sink available for heat rejection. During the temperature measurements ambient room temperature was 22.1 °C.

POWER SUPPLY WITH XSIS-094 INSTALLED												
Output Voltage VDC	Output Amperage A	A °C	B °C	C °C	D °C	E °C	F °C	G °C	H °C	I °C	J °C	K °C
26.254	2.0	32.8	32.9	33.5	33.1	33.1	33.1	32.1	32.6	32.8	36.8	37.7
26.325	5.0	36.8	36.8	37.1	37.2	36.9	37.3	36.7	36.3	36.1	41.1	40.5
26.230	12.0	50.3	50.2	50.5	49.7	50.0	50.0	48.6	48.0	49.4	68.4	66.1
26.302	15.0	59.3	60.4	63.0	61.5	63.3	63.5	60.6	60.3	61.6	107.3	92.0

POWER SUPPLY WITH XSIS-095 INSTALLED												
Output Voltage VDC	Output Amperage A	A °C	B °C	C °C	D °C	E °C	F °C	G °C	H °C	I °C	J °C	K °C
26.427	2.0	32.0	32.0	32.3	31.7	31.9	32.4	32.6	32.8	32.2	32.3	34.6
26.410	5.0	37.0	37.5	36.9	36.8	36.9	37.0	36.6	37.2	36.9	39.0	40.1
26.420	12.0	53.6	53.7	54.6	52.9	53.7	53.9	52.1	52.0	52.7	66.7	69.3
26.413	15.0	54.3	57.3	58.5	53.6	57.0	58.1	55.1	52.8	55.2	61.2	56.4

As the data shows, the power supply with the XSIS-095 transistors operated cooler temperatures than the unit with the XSIS-094 transistors, especially at the higher load values. Both power supplies operated successfully at 26.4 VDC and 15.0 A. (greater than 80% of rated load of 18.0 A.) for over 48 hours. At the end of the 48 hour period, additional stress testing began.

The stress testing included increasing the load applied to each power supply in 1.0 A increments allowing the power supply temperatures to stabilize and recording the heat sink and output transistor temperatures as before.

TEMPERATURE MEASUREMENTS AT 16 AMP LOAD.

POWER SUPPLY WITH XSIS-094 INSTALLED AT 16.0 A LOAD												
Output Voltage VDC	Output Amperage A	A °C	B °C	C °C	D °C	E °C	F °C	G °C	H °C	I °C	J °C	K °C
26.4	16.0	53.8	56.2	57.2	55.5	49.1	53.6	51.3	55.8	58.4	81.2	79.2

POWER SUPPLY WITH XSIS-095 INSTALLED AT 16.0 A LOAD												
Output Voltage VDC	Output Amperage A	A °C	B °C	C °C	D °C	E °C	F °C	G °C	H °C	I °C	J °C	K °C
26.4	16.0	58.5	59.5	60.0	58.6	58.3	60.4	57.6	57.3	56.8	79.5	77.4

TEMPERATURE MEASUREMENTS AT 17 AMP LOAD.

POWER SUPPLY WITH XSIS-094 INSTALLED AT 17.0 A LOAD												
Output Voltage VDC	Output Amperage A	A °C	B °C	C °C	D °C	E °C	F °C	G °C	H °C	I °C	J °C	K °C
26.4	17.0	63.3	63.5	67.7	63.3	64.6	63.5	61.7	63.3	64.5	108.8	95.3

POWER SUPPLY WITH XSIS-095 INSTALLED AT 17.0 A LOAD												
Output Voltage VDC	Output Amperage A	A °C	B °C	C °C	D °C	E °C	F °C	G °C	H °C	I °C	J °C	K °C
26.4	17.0	64.6	65.9	69.4	63.5	65.8	65.9	64.0	66.0	65.0	101.5	98.5

At approximately 17.5 Amps the power supply with XSIS-094 transistors failed. The failure was consistent with other failures observed, Q15, Q16 and R1 had all failed open. Stress testing continued on the power supply with XSIS-095 installed. Final testing for the unit was at 26.4 VDC and 19.0 A. the following temperatures were recorded:

POWER SUPPLY WITH XSIS-095 INSTALLED AT 19.0 A LOAD												
Output Voltage VDC	Output Amperage A	A °C	B °C	C °C	D °C	E °C	F °C	G °C	H °C	I °C	J °C	K °C
26.4	19.0	76.7	81.5	84.6	76.6	81.5	85.5	75.7	72.4	78.9	130.6	127.3

IRI believes that the excessive heat observed for the unit with XSIS-094 is due to insufficient drive available coupled with the low gain h_{FE} of the transistor, as was predicted by preliminary testing and Kepco, Inc., analyses.

RECOMMENDATIONS

Integrated Resources, Inc., with Kepco, Inc.'s concurrence recommends that transistors Q15 and Q16 be replaced with XSIS-095 and that all age related aluminum electrolytic capacitors be replaced on all Kepco, Inc., RMX 24-D-20804 power supplies which are returned for refurbishment.

Integrated Resources, Inc., recommends that each individual nuclear facility with KEPCO, Inc., power supplies installed evaluate the systems and usage of the power supplies and based on the power supplies criticality to the systems operability determine whether the individual power supplies should be refurbished.

CONCLUSION

Integrated Resources, Inc., (IRI) observed that "SAFETY RELATED" power supplies provided by two customers for refurbishment had failed in exactly the same manner. During discussions with KEPCO, Inc., the original equipment manufacturer, IRI was advised that transistors Q15 and Q16 were "marginal". Based on KEPCO's analysis IRI reported a possible design deficiency as required by IRI's QA Program and 10 CFR 21 to the U. S. Nuclear Regulatory Commission verbally on 3/24/95 and in writing on 3/27/95.

Since the notifications Integrated Resources, Inc., has selected a replacement transistor XSIS-095 and thoroughly tested the Kepco, Inc., Model RMX 24-D-20804 power supplies with the replacement transistors installed. Integrated Resources, Inc., believes that replacement of Q15 and Q16 with XSIS-095 when coupled with replacement of the aluminum electrolytic capacitors provides a long term solution to the original problems associated with these power supplies.

REFERENCES

1. Fax of memo dated 3/24/95 from Mr. J. Kiviranna, KEPCO, Inc., Senior Applications Engineer, to Integrated Resources, Inc., concerning voltage ratings of Q15 and Q16.
2. Fax of memo dated 4/6/95 from Mr. J. Kiviranna, KEPCO, Inc., Senior Applications Engineer, to Integrated Resources, Inc., concerning review of IRI testing.
3. Fax of Shindengen T20M40 and 2SC2507 transistor data sheet from Data Digest.
4. Fax of Fuji Electric Co., Ltd. data sheets for 2SC2930 and 2SC2930-06 transistors from Collmer Semiconductor.

REFERENCES

FAX MEMO	T O	Company Integrated Resources, Corp.	F R O M	**KEPCO, INC., NEW YORK**
		Name John Brosemer		Name John Kiviranna
No. (1/1)		CC Sarkis Nercessian		Fax No. 718-767-1102
Date 03/24/95		Fax No. (402) 873-5809		Tel. No. 718-461-7000

Attention: John Brosemer

Re: Our telephone conversations of 23 and 24 March, 1995

Subject: Main power switching transistors for model RMX 24-D-20804

It has recently come to my attention that there have been random failure of the power switching transistors in the RMX 24-D-20804.

In discussing this mater with Sarkis Nercessian, our Chief Electronics Engineer, it has been concluded that the voltage rating of transistors Q15 & Q16 are marginal. The calculated voltage stress may reach 428 Vdc at high line. The calculated current stress may reach 3.5 Adc at low line.

The calculations are based upon the chapter on Half-Bridge and Full-Bridge Converters in <u>SWITCHING POWER SUPPLY DESIGN</u>, published by McGraw-Hill.

We therefore recommend that you institute a policy of replacing all the non-2SD380 transistors at the earliest possible opportunity.

The voltage ratings of capacitors C8 and C9 entirely adequate for the task.

Best regards,

John Kiviranna

John Kiviranna
Senior Applications Engineer

CC Frank Tolch

FAX MEMO	TO	Company Integrated Resources, Corp.	FROM	KEPCO, INC., NEW YORK
		Name John Brosemer		Name John Kiviranna
No. (1/1)		CC Sarkis Nercessian		Fax No. 718-767-1102
Date 04/06/95		Fax No. (402) 873-5809		Tel. No. 718-461-7000

Attention: John Brosemer

Subject: RMX 24-D-20804

We have reviewed the results of your fax dated 4 April 1995. We concur that the XSIS-095 [redacted] are well suited to this task.

Best regards,

66 DE 0923515 0000178 3

新電元 SHINDENGEN 半導体素子 ● SEMICONDUCTOR

0923515 ARISTO-CRAFT 66C 00178 D T-03-01 T·33·01

ファストリカバリダイオード Fast Recovery Diodes

品名	IO (A)	VRM (V)	IFSM (A)	VF (max.) (V)	IR (max.) (μA)	trr (max.) (nS)	外形図
D1K20	0.6	200	25	1.2	10	300	1
D1K40		400		1.3			
D1K20H		200		1.2		100	
S2K20	1.2	200	50	1.1	10	300	1
S2K40		400		1.3			
S2K20H		200		1.1		100	
S3K40	1.8	400	60	1.2	10	300	1
S6K20	6	200	120	1.2	10	300	15
S6K40		400		1.3			
S6K20H		200		1.2		100	

● センタタップ

品名	IO (A)	VRM (V)	IFSM (A)	VF (max.) (V)	IR (max.) (μA)	trr (max.) (nS)	外形図
S5KC20	5	200	50	1.2	10	300	23
S5KC40		400					
S5KC20H		200				100	
S5KC20R		200				300	
S6KC40R		400					
S6KC20RH		200				100	
S12KC20	12	200	120	1.2	10	300	24
S12KC40		400					
S12KC20H		200				100	

ファストリカバリダイオード Fast Recovery Diodes

● ダブラタイプ

品名	IO (A)	VRM (V)	IFSM (A)	VF (max.) (V)	IR (max.) (μA)	trr (max.) (nS)	外形図
S6KD20	6	200	50	1.2	10	300	23
S6KD40		400		1.3			
S6KD20H		200		1.2		100	

サイダック（2方向2端子サイリスタ） SIDAC Bidirectional diode thyristors

品名	色別	IT (A)	VDRM (V)	ITSM (A)	VBO (V)	IBO (max.) (mA)	VT (max.) (V)	外形図
K1V5	赤	1	45	15	45～60	0.5	1.5	1
K1V6	金				55～65			
K1V10	銀		90		95～113			
K1V11	黄				104～118			
K1V12	緑				110～125			
K1V14	青		115	20	125～160			
K1V16	紫				145～170			
K1V22	灰		180		200～230			
K1V24	黒				220～250			
K1V26	白				240～270			

パワートランジスタ POWER TRANSISTOR

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高速スイッチング F1 series High Speed Transistors

型名	EIAJ No.	VCBO (V)	VCEO (V)	IC (A)	PT (W)	hFE min	スイッチング タイム (μS) max. ton	ts	tf	外形図
T3V40F1	2SC2501	500	400	3	40	15	1	3	0.7	27
T6V40F1	2SC2502			6	50					
T8W40F1	2SC2937			8	80					28
T10W40F1	2SC2938			10	100					
T3M40F1	2SC2505			3	60					29
T6M40F1	2SC2506			6	80					
T8M40F1	2SC2282			8	80					30
T10M40F1	2SC2283			10	100					
T20M40F1	2SC2507			20	200					31

高速スイッチング F2 series High Speed Transistors

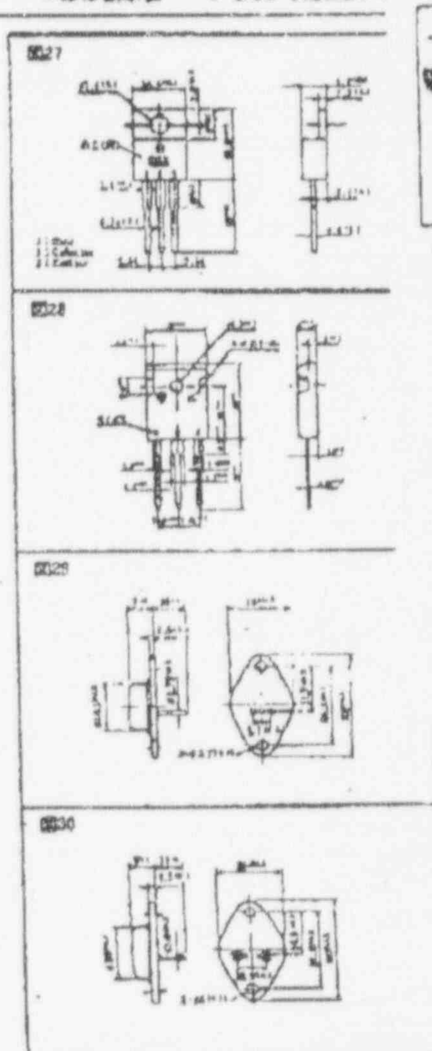
型名	EIAJ No.	VCBO (V)	VCEO (V)	IC (A)	PT (W)	hFE min	ton	ts	tf	外形図
T3V40F2	2SC2826	500	400	3	40	10	1	2	0.5	27
T6V40F2	2SC2827			6	60					
T10W40F2	2SC2939			10	100					28
T10M40F2	2SC2829			10	100					30
T20M40F2	2SC2830			20	200					31

超高速スイッチング F3 series Ultra High Speed Transistors

型名	EIAJ No.	VCBO (V)	VCEO (V)	IC (A)	PT (W)	hFE min	ton	ts	tf	外形図
T6V20F3	2SC3219	250	250	6	60	10	0.3	0.5	0.1	27
T10W20F3	2SC3220			10	100					28
T6M20F3	2SC3221			6	80					29
T10M20F3	2SC3222			10	100					30
T20M20F3	2SC3223			20	200					31
T30M20F3	2SC3224			30	300					32
T3V40F3	2SC3162	500	400	3	40	10	0.3	1.0	0.1	27
T6V40F3	2SC3163			6	50					
T10W40F3	2SC3164			10	100					28
T3M40F3	2SC3165			3	60					29
T6M40F3	2SC3166			6	80					
T10M40F3	2SC3167			10	100					30
T20M40F3	2SC3168			20	200					31

高耐圧・高速スイッチング High Voltage, High Speed

型名	EIAJ No.	VCBO (V)	VCEO (V)	IC (A)	PT (W)	hFE min	ton	ts	tf	外形図
T3V80	2SC3259	800	800	3	40	7	0.5	3.0	0.7	27
T3W80	2SC3260				50					28
T6V80	2SC3579			6	50					27
T6W80	2SC3261				80					29
T10W80	2SC3262			10	100					



Post-it™ brand fax transmittal memo 7671 # of pages ▸ 1
To John Bosworth From Pres Cgelon
Co. Co.
Dept. Phone # 303-399-2358
Fax # 402-873-5859 Fax # 649-9445

パワートランジスタ POWER TRANSISTORS

SHINDENGEN ELECTRIC MFG 32E D ■ 6219387 0000018 0 ■SHEJ

高耐圧・超高速スイッチングトランジスタ High Voltage・Ultra High Speed Switching Transistors

T-35-19

FS series

品名 EIAJ No.	Type No.	V_{CBO} [V]	V_{CEO} [V]	V_{EBO} [V]	I_C [A]	I_B [A]	P_T [W]	Tstg [℃]	Tj [℃]	V_{CEO} (sus) (min) [V]	h_{FE} (min)	V_{CE} (sat) (max) [V]	V_{BE} (sat) (max) [V]	θjc (max) [℃/W]	f_T (std) [MHz]	ton (max) [μS]	ts (max) [μS]	tf (max) [μS]	外形 No. Outline No.
2SC3219	T6V20F3				6	2	50							2.5					Fig. 1
3220	T10W20F3				10	4	80							1.56					Fig. 3
3221	T6M20F3	230	230	7	6	2	60	−55～+150	+150	200	10	1	1.6	1.66	20	0.3	0.5	0.1	Fig. 4
3222	T10M20F3				10	4	100							1.25					Fig. 5
3223	T20M20F3				20	7	200							0.62					Fig. 6
3162	T3V40F3				3	1	40							3.13					Fig. 1
3163	T6V40F3				6	2	50							2.5					
3164	T10W40F3				10	4	100							1.25					Fig. 3
3165	T3M40F3	500	400	7	3	1	60	−55～+150	+150	400	10	1	1.5	2.08	20	0.3	1	0.1	Fig. 4
3166	T6M40F3				6	2	80							1.56					
3167	T10M40F3				10	4	100							1.25					Fig. 5
3168	T20M40F3				20	7	200							0.62					Fig. 6

高耐圧高速スイッチングトランジスタ High Voltage・High Speed Switching Transistors

FX series

品名 EIAJ No.	Type No.	V_{CBO} [V]	V_{CEO} [V]	V_{EBO} [V]	I_C [A]	I_B [A]	P_T [W]	Tstg [℃]	Tj [℃]	V_{CEO} (sus) (min) [V]	h_{FE} (min)	V_{CE} (sat) (max) [V]	V_{BE} (sat) (max) [V]	θjc (max) [℃/W]	f_T (std) [MHz]	ton (max) [μS]	ts (max) [μS]	tf (max) [μS]	外形 No. Outline No.
2SC4061	T3V45FX				3	1	40							3.12					Fig. 1
4062	TP3V45FX				3	1	25							5					Fig. 2
4063	T5V45FX				5	2	50							2.5					Fig. 1
4064	TP5V45FX				5	2	30							4.16					Fig. 2
4065	T8V45FX	600	450	7	8	4	60							2.08					Fig. 1
4066	TP8V45FX				8	4	45	−55～+150	+150	450	10	1	1.5	2.77	20	0.5	2	0.2	Fig. 2
4067	T8W45FX				8	4	80							1.56					
4058	T10W45FX				10	4	100							1.25					Fig. 3
4059	T15W45FX				15	6	150							0.56					
4060	T20W45FX				20	7	156							0.63					
3716	T20W40PX	500	400		20	7	200			400				0.625				0.3	Fig. 10

外形図 Outline Dimensions

[Unit : mm]

Fig. 1

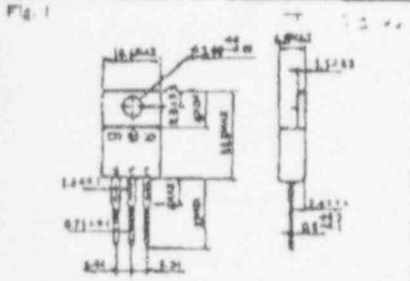


Fig. 2

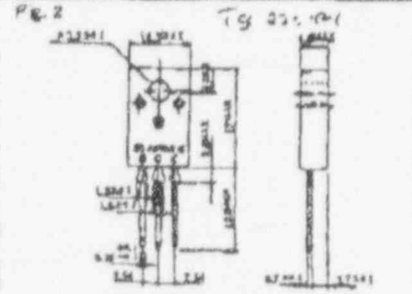
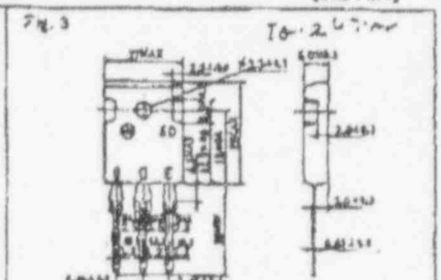


Fig. 3



To: John
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Integrated Resources

2SC2930

3 pages

8 High speed switching darlington transistors

- These are of darlington type and are provided with a higher h_{FE}.
- Switching speed is in the range of t_f 1μs.
- Best suited to switching regulator and motor control applications

Device type	V_{CBO} Volts	V_{CEO} Volts	V_{CEO} (sus) Volts	I_C cont. Amps.	P_C Watts	h_{FE} min.	I_C Amps.	V_{CE} Volts	Switching time (Max.) t_{on} μsec.	t_{stg} μsec.	t_f μsec.	Package	Net weight Grams	Equivalent circuit Page 40
ETG36-040C	500	500	400	20	175	50	10	5	0.8	2.5	1.0	TO-3	17	Fig. B6
ETG36-040D	500	500	400	20	175	50	10	5	0.8	2.5	1.0	TO-3	17	Fig. B9

Note: These are available in two versions – i.e. with built-in fast recovery diode or without. Please select the version best suited for your purpose.

9 Power darlington transistors

- The DC current gain is very high.
- Highly versatile

Device type	V_{CBO} Volts	V_{CEO} Volts	V_{CEO} (sus) Volts	I_C cont. Amps.	P_C Watts	h_{FE} min.	I_C Amps.	V_{CE} Volts	Switching time (Max.) t_{on} μsec.	t_{stg} μsec.	t_f μsec.	Package	Net weight Grams	Equivalent circuit Page 40
2SD1797	60	80	50	7	30	800	3	1.5	—	—	—	TO-220F	2.5	Fig. B3
2SD833	80	80	80	7	60	2000	3	3	1.0	5.0	1.0	TO-220AB	2	Fig. B4 *
2SD916	80	80	80	7	40	1000	3	1.5	1.0	5.0	1.0	TO-220AD	2	Fig. B4 *
2SD1726	150	100	80	7	25	400	5	2	2.0	15	2.0	TO-220F	2.5	Fig. B3
2SD834	250	200	180	4	25	1500	2	2	1.7	15	10	TO-220AB	2	Fig. B2
2SD1[illegible]73	300	250	250	4	[illegible]	1000	2	2	3	15	10	TO-220AB	2	Fig. B1
2SD[illegible]70	[illegible]	300	300	6	40	500	4	2	—	—	—	TO-220F	2.5	Fig. B8
2SD1071	450	450	300	6	40	500	4	2	3	15	10	TO-220AB	2	Fig. B8
2SD835	400	400	350	6	40	400	4	1.5	1.0	12.0	6.0	TO-220AB	2	Fig. B4 *
2SD1072	500	500	350	5	60	500	3	1.5	1.5	12.0	6.0	TO-220AB	2	Fig. B3
ET366	60	60	50	7	40	4000	3	3	—	—	—	TO-220F	2.5	Fig. B4 *
ET378	100	100	100	10	80	1000	6	2	—	—	—	TO-3P	6	Fig. B4 *
ET370	100	100	100	15	100	1000	8	3	—	—	—	TO-3P	6	Fig. B4 *
ET393	150	100	100	10	80	700	3	4	—	—	—	TO-3P	6	—
ET386	300	250	250	4	40	1000	2	2	—	—	—	TO-3PF	6	Fig. B1
ET365	450	450	300	8	40	500	4	2	—	—	—	TO-220F	2.5	Fig. B1
ET385	400	400	350	6	40	500	4	2	—	—	—	TO-220F	2.5	Fig. B8
ET375	400	400	350	6	40	400	4	1.5	1.0	12.0	6.0	TO-220F	2.5	Fig. B4 *
ET375	650	450	450	15	80	100	15	5	1.0	12.0	2.0	TO-3P	6	Fig. B7 *

* Without B0 terminal

10 Large current speed switching transistors

- The I_C can handle large current (30 Amps) yet the switching speed is very high.
- Efficient parallel operation
- Motor speed controls, inverter and chopper use

Device type	V_{CBO} Volts	V_{CEO} Volts	V_{CEO} (sus) Volts	I_C cont. Amps.	P_C Watts	h_{FE} min.	I_C Amps.	V_{CE} Volts	Switching time (Max.) t_{on} μsec.	t_{stg} μsec.	t_f μsec.	Package	Net weight Grams
2SC2930	650	400	400	30	200	15	10	5	1.0	3.0	1.0	TO-3	19

and Characteristics of Fuji Power Transistor

2SC2930-06

1. Outline Drawings : See Next Page
2. Absolute Maximum Ratings (T_c=25℃)

Item	Symbol	Rating	Unit
Collector-Base Voltage	V_{CBO}	500	V
Collector-Emitter Voltage	V_{CEO}	400	V
Collector-Emitter Voltage	$V_{CEO(SUS)}$	400	V
Emitter-Base Voltage	V_{EBO}	10	V
Collector Current	I_C	20	A
Base Current	I_B	8	A
Collector Disspation	P_C	200	W
Operating Temperature	T_j	+150	℃
Storage Temperature	T_{stg}	−65 ~ +150	℃

3. Electrical Characteristics (T_c=25℃)

Item	Symbol	Conditions	Min	Max	Unit
Collector-Base Voltage	V_{CBO}	I_{CBO} = 1mA	500		V
Collector-Emitter Voltage	V_{CEO}	I_{CEO} = 10mA	400		V
Collector-Emitter Voltage	$V_{CEO(SUS)}$	I_C = 1A	400		V
Emitter-Base Voltage	V_{EBO}	I_{EBO} = 1mA	10		V
Collector Cut-off Current	I_{CBO}	V_{CBO} = 500V		1.0	mA
Emitter Cut-off Current	I_{EBO}	V_{EBO} = 10V		1.0	mA
DC Current Gain	h_{FE}	I_C = 10A V_{CE} = 5V	22		
Collector Saturation Voltage	$V_{CE(sat)}$	I_C = 20A		1.0	V
Emitter Saturation Voltage	$V_{BE(sat)}$	I_B = 4A		1.25	V
Switching Time	ton	I_C = 20A, I_{B1} = 4A, I_{B2} = 4A, Duty = 2%, R_L = 10Ω, PW = 20μs		1.0	μs
	tstg			3.0	μs
	tf			1.0	μs

(a) hFE 17→22 [illegible] 62-11-30 [illegible]
(b) 1/10 [illegible] 63-1-7 [illegible]

	DATE	NAME	APPROVED
DRAWN	62-11-6	[illegible]	
CHECKED	62-11-7	[illegible]	

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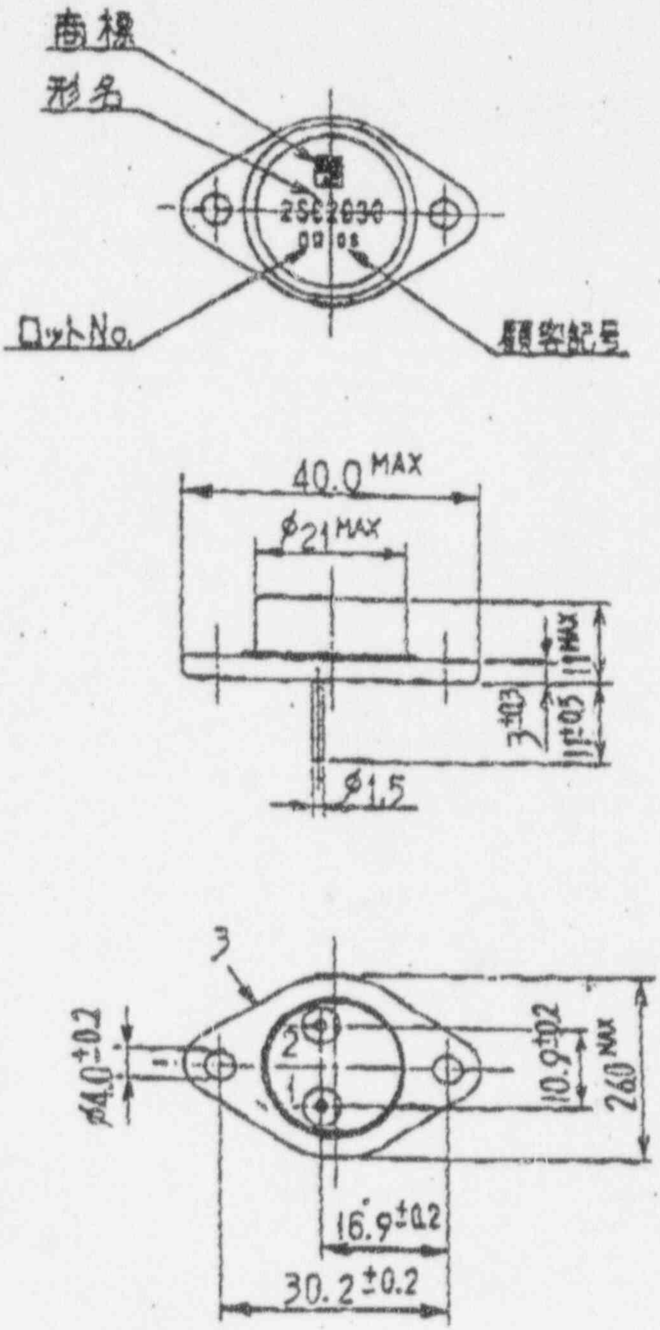
Item	Symbol	Conditions	Min	Max	Unit
Thermal Resistance	Rth(j-c)	Junction to Case		0.62	℃/W

* Outline Drawings



電極接続

1. ベース
2. エミッタ
3. コレクタ(ケース)

準拠外形規格

JEDEC---TO-3
EIAJ----TC-3
TB-3

	DATE	NAME	APPROVED
DRAWN	- -	[redacted]	
CHECKED	- -		

REVISIONS

Fuji Electric Co.,Ltd

DWG.NO. MS5B0147 2/10

INTEGRATED RESOURCES, INC.

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Company:

Regarding: KEPCO, INC RMX 24-D-20804 POWER SUPPLY RECOMMENDATIONS AND SUGGESTED CORRECTIVE ACTIONS; EVENT NO. 28585

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