

# APPLICATION

## NOTE

 **TELEDYNE RELAYS**

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### **RF Power Handling Capability**

**This application note addresses the capability of contacts in Teledyne Relays' TO-5 and Centigrid<sup>®</sup> relays to switch and carry RF power.**

**This information is applicable to the following relay families:**

**RF100  
RF103  
RF300  
RF303  
RF310  
RF313  
RF320  
RF323**

# APPLICATION

## NOTE



### I. INTRODUCTION

Teledyne Relays offers a number of switching solutions for high speed signals with the classic TO-5 style and Centigrad® RF relays. The design of these relays has been tailored to address the unique requirements of high speed signal transfer regardless whether these signals are in the frequency or the time domain. To date, RF relays offered by Teledyne Relays have been characterized with respect to the traditional RF parameters of Isolation, Insertion Loss and VSWR. This application note is presented as a general guide line for the RF design engineer in need of understanding the RF power handling capabilities of the following RF relays offered by Teledyne Relays:

RF100

RF103

RF300

RF303

RF310

RF313

RF320

RF323

As the data presented will show, Teledyne Relays' TO-5 and Centigrad® style relays have surprising RF power handling capabilities despite their ultraminiature size. Both relay package types are capable of carrying continuous power of up to 30W average at up to 2.0Ghz. Over the same frequencies, these RF relays are capable of hot switching a 20W RF load for a significant number of cycles.

These demonstrated power handling capabilities allow for many new applications beyond the power levels in which these relays have been used which has typically been on the order of 1 to 2W of RF power or less.

### II. BACKGROUND

The power handling capability of an RF relay is a complicated mechanism. An exact or even accurate mathematical model is very difficult, if not impossible to generate. The information and design curves provided in this application note have been derived from a combination of theoretical approximations and a series of experiments and tests conducted by Teledyne Relays.

#### **Power Carry vs. Power Hot Switching**

All electromechanical relays have two distinct methods of transferring power; hot switching and carrying. When a relay is hot switched, it means the load is connected or disconnected by the closing or opening of the relay contacts. When a relay carries power, the relay contacts have been closed prior to the introduction of the load into the circuit and circuit closure is accomplished by some other mechanism. Typically, carrying a load will tend to prolong relay life and allow the use of higher power levels.

These two types of contact utilization affect relay contacts in different ways:

# APPLICATION

## NOTE



### • Hot Switch Capability

The contact configuration of all Teledyne electromechanical relays is double throw, break-before-make. Under hot switching conditions, when the contacts are in transition, the incident RF power will be momentarily reflected back to the source. During this short period in which the contacts exhibit an open circuit condition, the opening contact develops an arc (corona). This arc generates high temperature areas on the contact surface and can severely erode the contact plating. Eventually, the surface erosion is sufficient to detrimentally affect RF performance. The degree of erosion is directly related to the input RF power level.

### • Carry Capability

When relay contacts carry power they are statically directing it. There are two factors which effect a relays capability to carry RF power:

#### Heat

Heat is generated by intrinsic ohmic losses. Ohmic loss is a function of two factors, the bulk resistance of the circuit and constriction resistance. Bulk resistance is the sum of all resistance in a path. Constriction resistance is a function how well the contact surfaces mate physically. These ohmic loss factors become more pronounced with increasing frequencies. Therefore, an effective heat dissipation structure between the relays and the surrounding environment is essential to maximize a relay's power handling capability.

#### Break Down Voltage

An appropriate air gap between the RF path represented by the contacts and adjacent ground structures is essential. The size of the gap, also known as dielectric spacing, determines the maximum peak RF power which a relay can carry without a voltage breakdown.

Because of the differences between hot switching and carrying, life expressions must be gauged in different ways. Hot switching results in a reduced power handing capability but requires no special circuit sequencing and life is defined in numbers of cycles. Carrying on the other hand, allows higher power handling but requires special circuit sequencing and life is referenced as a time scale and/ or numbers of applied pulses.

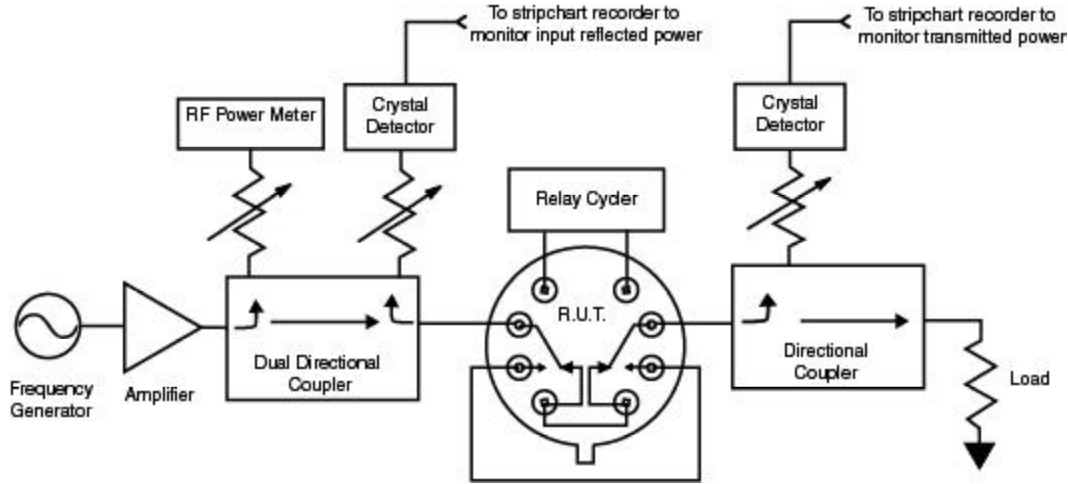
### III. RF POWER TEST

The test setup for the RF power testing is illustrated in Fig 1. The relay under test (RUT) was soldered to a PCB approximately 2" x 2". The PCB material was 0.030" Duriod 6000® copper clad PTFE. The PCB with the attached RUT was mounted on a vise and placed on a test bench in a laboratory environment. A thermocouple was mounted to the case of the RUT to monitor the relay case temperature.

# APPLICATION

## NOTE

 **TELEDYNE RELAYS**



**Fig. 1**

### A. Power Carrying Test

The test set up was as previously mentioned, there was no heat sink of any type used during the test. During the test, the RUT was energized with nominal voltage. This creates a worst case test condition due to the heat generated by the energized coil as well as the heat generated by the power in the contact area. The relay was in a 25°C ambient environment.

After calibration of the test system, a continuous RF power signal of 30W cw at 2GHz was applied to the contacts of the RUT. The RF power was continuously applied to the RUT in intervals of 3.5 to 10 hours. During the power test the input power, the reflected power and the output transmitted power, as well as, the RUT's case temperature were monitored.

The test was conducted in six different intervals for a cumulative total of 35 hours. The shortest interval being 3.5 hours and the longest interval being 10 hours.

Table 1 shows the schedule of testing for RF power carrying.

Date	Time	Hours	Power	Max. Case Temperature
6/13/98	8:00 AM - 2:00 PM	6	30 W	72 °C
6/16/98	9:00 AM - 7:00 PM	10	30 W	74 °C
6/17/98	10:30 AM - 6:30 PM	8	30 W	74 °C
6/20/98	8:00 AM - 4:00 PM	8	30 W	73 °C
6/21/98	9:30 AM - 1:00 PM	3.5	30 W	73 °C

**Table 1**

# APPLICATION

## NOTE



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### RF Power Carry Results

A total of 35 cumulative hours of 30W cw at 2GHz was applied to the RF303-5. The input reflected power and output transmit power were stable with respect to the input applied power throughout the test. The Relay case temperature increased from +25°C to +74°C in the first 15 minutes as RF power was applied. After that time case temperature stabilized and remained at +74°C. When the test was resumed, at the 7<sup>th</sup> interval, it was observed that the case temperature drastically increased to over +100°C. The test was terminated at that point. Investigation revealed that the temperature rise was caused by a short circuit condition in the PC board circuitry. Post test RF parametric evaluation was performed and insertion loss and VSWR were not significantly degraded from initial readings.

### B. Hot Switch Test

There were three separate hot switch tests performed on three RF303-5 relays. Two were subjected to 20W cw and one was subjected to 6.3W cw.

### Hot Switch Test Results

The first relay was exposed to 20W cw and successfully switched 35,000 cycles at which time it developed high insertion loss, on the order of 3dB and greater. After the test was terminated a DPA was performed. The relay contacts exhibited burn marks and low overtravel which could indicate a relaxation of the required contact pressures as a result of heating. It is not known whether low over travel was a result of the test or was a pre-existing condition.

The second relay that was exposed to 20W cw successfully switched 65,000 cycles, at which time it developed high insertion loss similar to the first relay. No DPA was performed on the second relay.

The third relay was subjected to 6.3W cw hot switching test. This relay successfully switched beyond 1,000,000 cycles. Post test electrical evaluation and RF parameters, indicate little change from values obtained prior to the test. Data for the hot switch test is summarized in Tables II and III.

## IV. CONCLUSION

Based on the power tests described in this application note, the following recommendations can be given as a guideline for RF power handling capability of Teledyne Relays' TO-5 and Centigrad® series of insertion loss repeatability relays as well as the "Bypass" series of TO-5 relays.

# APPLICATION

## NOTE



- Continuous Carry Power @ 2.0GHz: 30W cw Max
- Hot Switch @ 2.0GHz: 20W cw for 25,000 cycles max  
10W cw for 100,000 cycles max  
6.3W cw for 1,000,000 cycles

Figures II and III are presented as projections of power and life capabilities varying with respect to frequency and temperature.

### V. NOTES

1. All testing was performed at a set frequency which was 2.0 GHz. No intermodulation testing was performed. If there are multiple frequencies, users are encouraged to perform tests using their specific spectrum. The application of multiple frequencies to a single conduit can exacerbate the effects of power on that conduit. Unforseen harmonics can greatly amplify the aparent power resent in a system.
2. Both power carrying and hot switch capability will increase with lower frequency applications.
3. For any high power applications, carry or hot switching, a proper grounding for heat sinking is essential.
4. Data presented here is based on a limited number of samples. No on-going testing is performed. The data presented here are general guidelines and are not intended as specification limits. Users should always verify the suitability of any relay or other component for their application.

# APPLICATION

## NOTE

 **TELEDYNE RELAYS**

Relay Condition		Energized				De-Energized			
Parameter		VSWR	Insertion Loss (dB)	Contact Resistance (Ohms)	Coil Resistance (Ohms)	VSWR	Insertion Loss (dB)	Contact Resistance (Ohms)	Coil Resistance (Ohms)
Relay # 1	Initial values	1.12	0.51	0.127	385	1.92	1.04	0.091	385
	Post 35K cycles	1.11	0.60	0.411	398	37.9	12.3	open	398
Relay # 2	Initial values	1.17	0.54	0.121	383	1.85	1.01	0.88	383
	Post 50K cycles	1.16	0.55	0.128	383	1.83	0.96	0.93	383
	Post 65K cycles	1.16	0.55	0.122	385	1.83/15.6	1.00/11.0	0.91/open	385

**Table II 20W Hot Switch @ 2GHz**

Each cycle is monitored on a strip recorder.

Relay # 1 exhibited intermittent contact conditions about 2,000 cycles prior to failure which was at about 35,000 cycles.

Relay # 2 exhibited intermittent contact conditions at about 65,000 cycles.

# APPLICATION

## NOTE



Relay Condition	Energized				De-Energized			
Parameter	VSWR	Insertion Loss (dB)	Contact Resistance (Ohms)	Coil Resistance (Ohms)	VSWR	Insertion Loss (dB)	Contact Resistance (Ohms)	Coil Resistance (Ohms)
Initial Value	1.14	0.53	0.128	390	1.89	1.00	0.091	390
Post 27K Cycles	1.13	0.57	0.131	392	1.89	1.04	0.091	392
Post 50K Cycles	1.12	0.57	0.130	394	1.89	1.03	0.098	394
Post 100K Cycles	1.12	0.56	0.136	393	1.90	1.09	0.090	393
Post 150K Cycles	1.13	.057	0.127	396	1.90	1.09	0.086	396
Post 250K Cycles	1.13	0.57	0.116	396	1.90	1.04	0.090	396
Post 1.1M Cycles	1.11	0.56	0.123	397	1.86	1.04	0.083	397

**Table III Hot Switch @ 2GHz**

Power level is from 6.5 to 7.0W cw.  
Case temperature rise is 14° to 15°C.



# APPLICATION

## NOTE

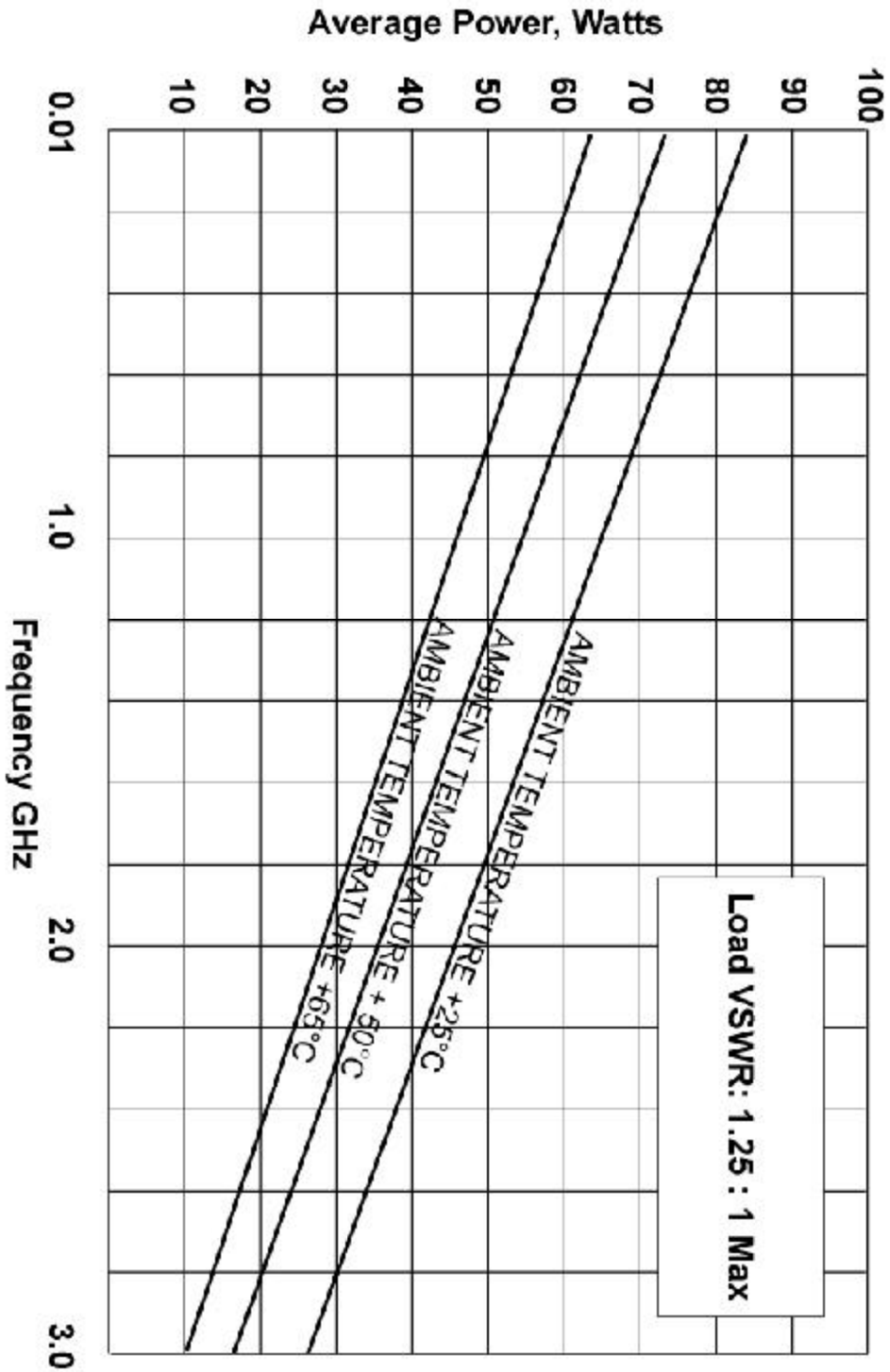


FIGURE II POWER CARRYING CAPABILITY

# APPLICATION

## NOTE

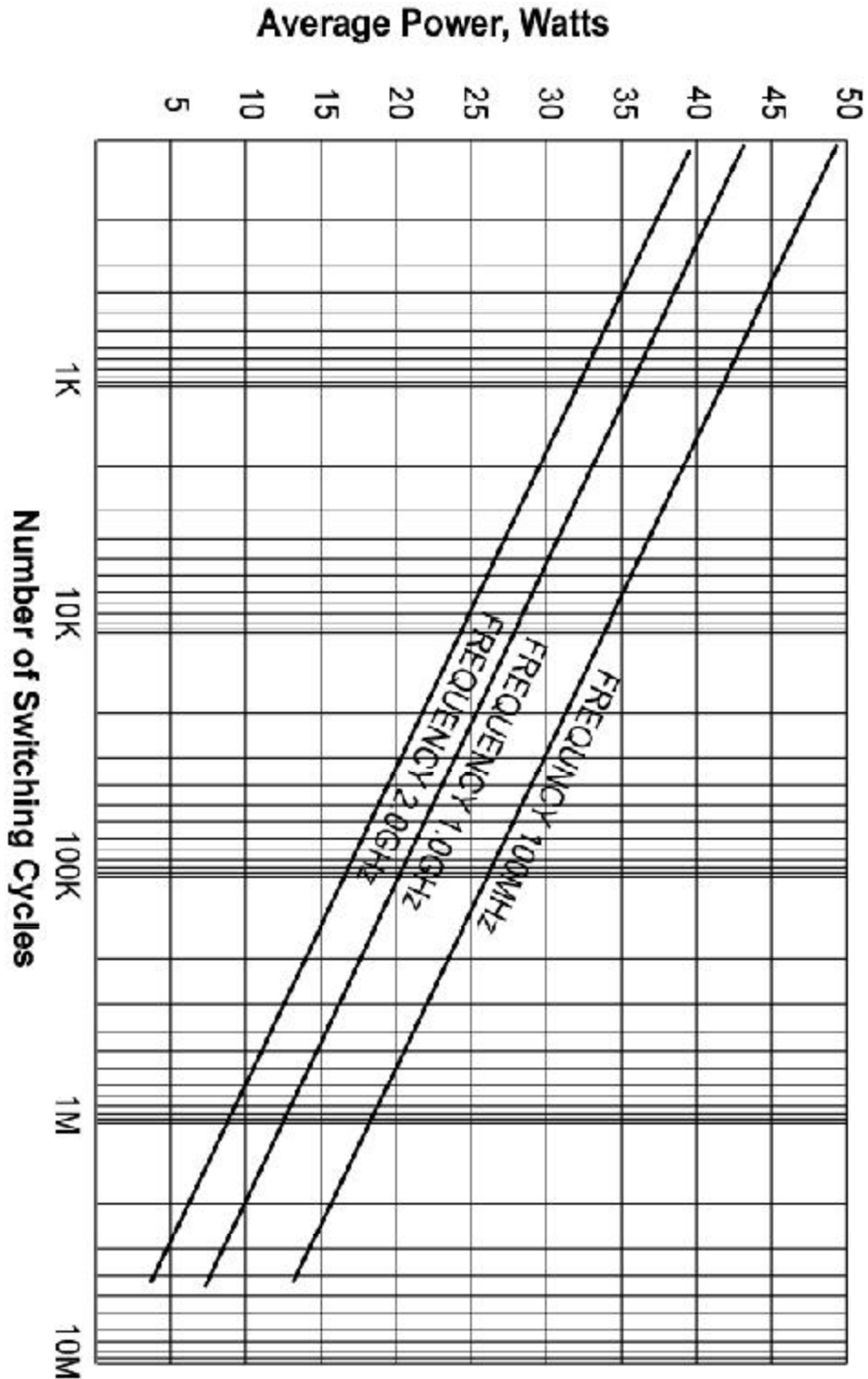


FIGURE III, HOT SWITCHING CAPABILITY @25°C