Hermetic Tantalum Capacitors

For High Power Pulse Applications

Charlie Dewey • April 12, 2017

EVANS CAPACITOR Company

www.evanscap.com

EVANSCAPS™

Advanced Capacitors for Demanding Applications!

INTRODUCTION

72 Boyd Avenue – East Providence, RI 02914 USA
T: 401-435-3555 www.evanscap.com

Evans Capacitor Company is a privately owned small business. We are a direct supplier to all Tier 1 defense contractors, ITAR Registered and AS9100/ISO2001 Certified. Incorporated in 1996, 2016 marks our 20th anniversary.

20 YEARS

- All products manufactured by ECC in USA
- All products are designed in house & built to order
- All units are 100% electrical tested & certified
- All units carry unique S/N for identification

nqa.
AS 9100
Registered

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HIGH POWER PULSE APPLICATIONS

LMCO- MEADS

NGC- Cobra Judy Replacement

Raytheon - NGJ

HIGH POWER PULSE

- PHASED ARRAY RADAR
  - GaN
  - GaAs
- JAMMING SYSTEMS
  - NGJ
- EW SYSTEMS
  - Directed Energy

NGC- E2D

Boeing / NGC - Wedgetail

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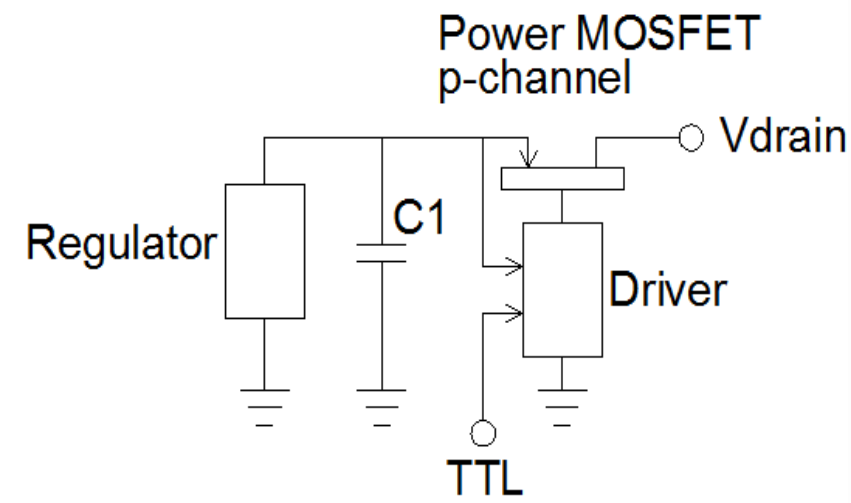
Why do we need High Power & Energy Storage?

"T/R modules, for defense radars, typically have high power amplifiers that require significant DC power during the transmit cycle of operation…..Each T/R module has a bank of capacitors to store energy that can help supply current during the transmit pulse to minimize voltage droop during the pulse. Voltage droop equates to RF power droop. Power conditioning is especially critical for long pulse waveforms."

From "Transmit Receive Modules for Radar and Communication Systems," R. Sturdivant, M. Harris, 2016 Artech House Publishing



C1 capacitor provides the energy required to drive the pulse. 75% to 90% of the pulse power must be stored here.

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GaN and GaAs on SiC (and diamond) can enable very high power T/R modules for modern phased array radars and other systems with 600w, 800w, and 1,000w designs.

Jamming and EW systems work in similar ways, demanding high power pulses to deliver jamming signals, EM bursts, etc.

These systems need very high power pulses to transmit and must ***maintain*** that power throughout the pulse without voltage droop.

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Additionally . . .

- GaN and GaAs on SiC (and diamond) enable very compact designs for T/R modules.
- New phased arrays, especially airborne, are much smaller and more powerful than previous technology allowed.
- Jamming and EW systems may be external pod configurations

Challenges . . .

- Highest power
- Most compact designs

We need . . .

New technology, high power energy storage to maximize performance, efficiency, and volumetric utilization.

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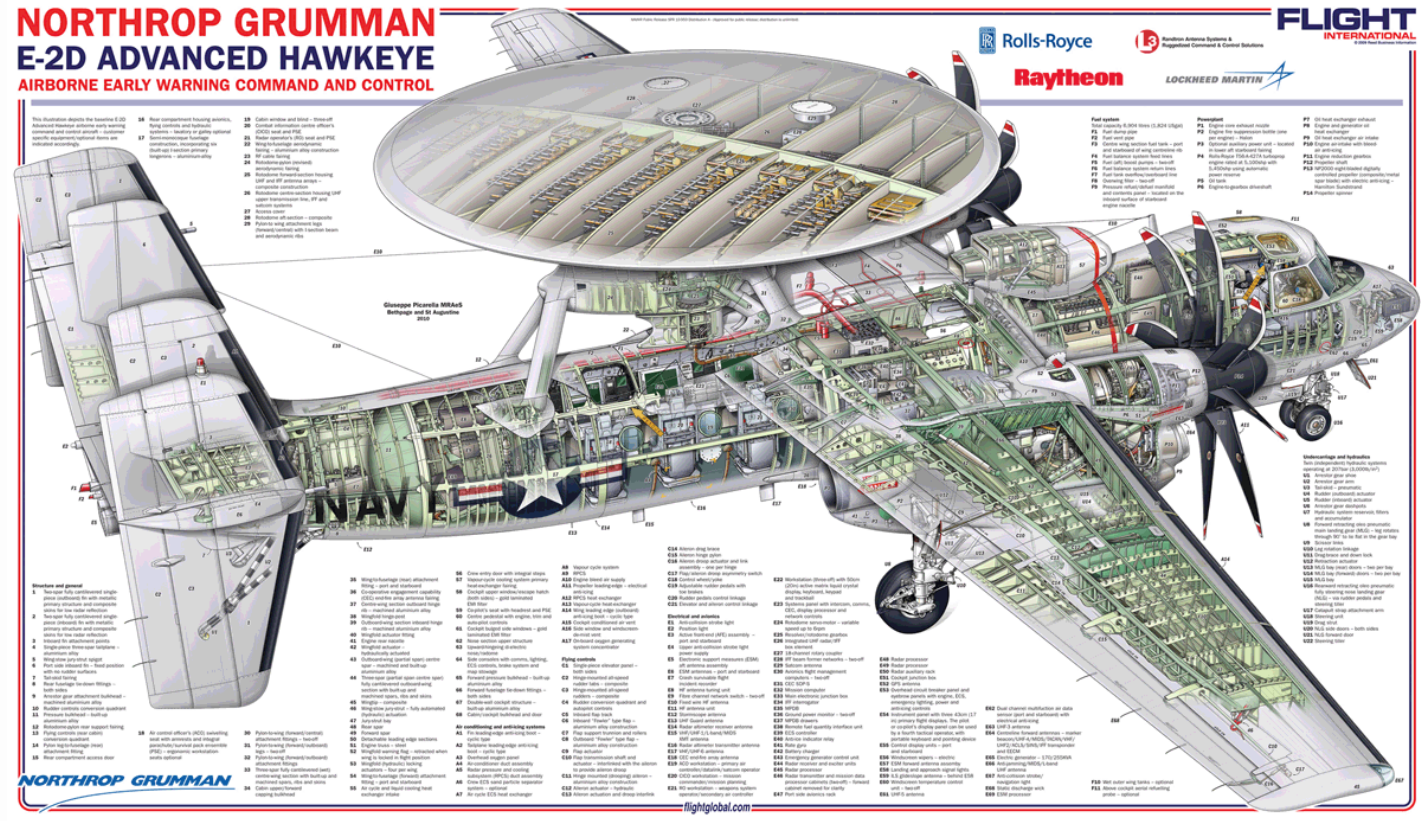
HIGH POWER PULSE APPLICATIONS

Why Space and Weight matter



NGC- E2D

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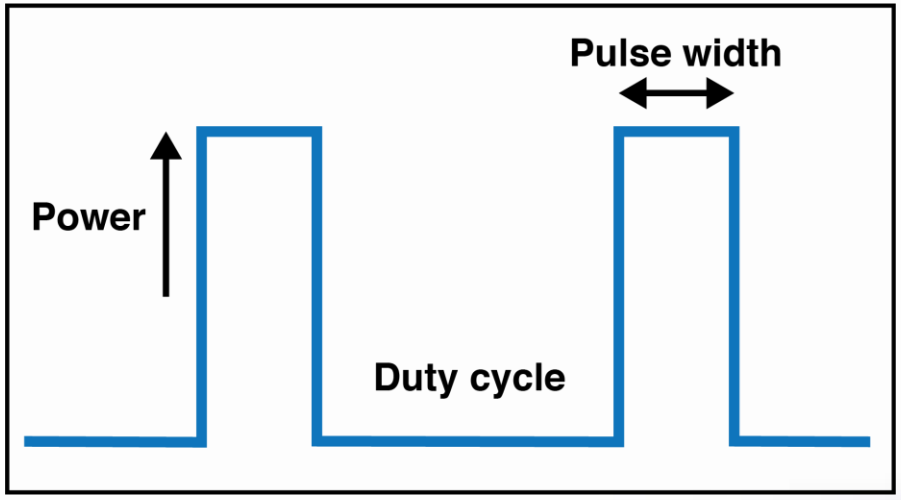
Radar and Jammers - How do we provide all that power?

- Higher operating voltage - 48V or 50V
- High current >20A
- Wider pulse width – 100µSec to mSec
- Aggressive duty cycles > 10%



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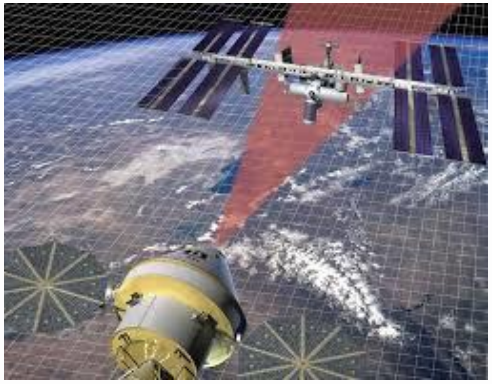
HIGH POWER PULSE APPLICATIONS

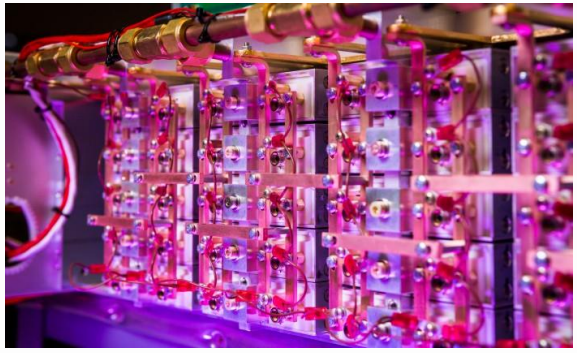
JSF EOTS



NASA LIDAR

HIGH POWER PULSE

- LASER TARGETING
- EW SYSTEMS
  - LASER Weapons
- RESEARCH LASERS
- LIDAR



HAPLS LASER Diode array

LLDR – targeting rangefinder

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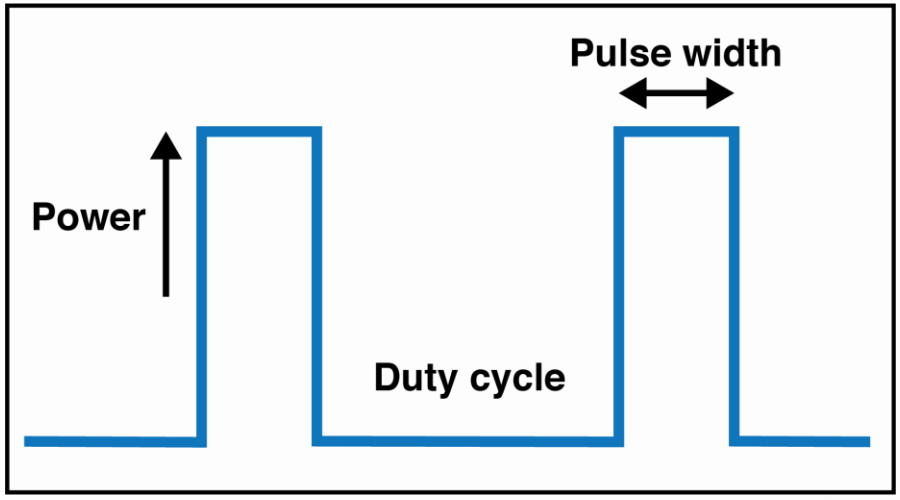
LASERs and such - How do we provide all that power?

- Higher operating voltage - 50V to 500V
- High current 200A – or more!
- Narrow very sharp pulse – 1 to 5µSec
- light duty cycles



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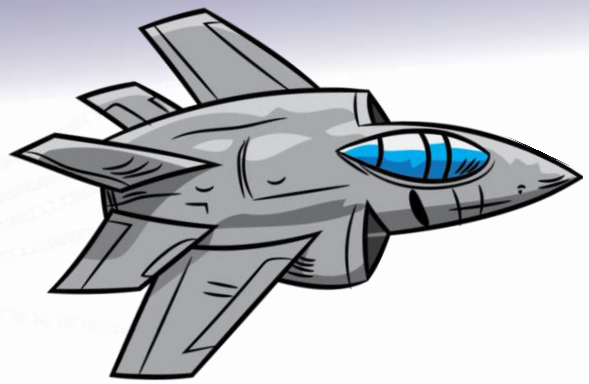

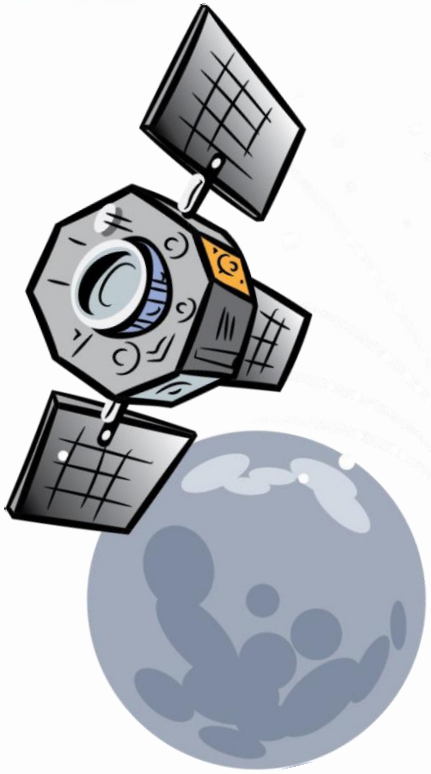

In Defense, Airborne, & Space systems for very high power our energy storage must . . .

- Provide sufficient energy to power the pulse
- Absorb high ripple current
- Filter voltage overshoot
- Cycle efficiently for life of system

With

- Minimum weight and volume
- Performance over temperature range
- Excellent heat transfer
- *Very* high reliability

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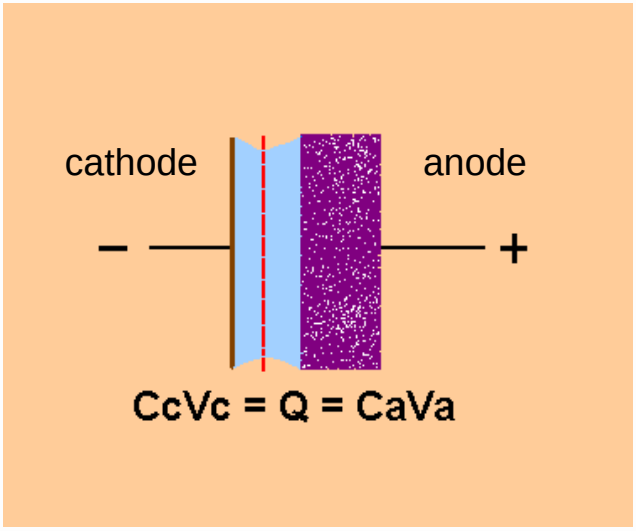
HYBRID CAPACITOR OPERATING PRINCIPLE

ELECTROLYTIC

ELECTROCHEMICAL

- Two electrodes are connected in series by an electrolyte.
- Ta_2O_5 dielectric (anode) withstands high voltages.
- High capacitance RuO_2 (cathode) increases volumetric efficiency.
- Liquid electrolyte – formulated for high reliability and long life.



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HYBRID CAPACITOR TECHNICAL ADVANTAGE

- High cell voltage – no series connections (up to 125V)
- Low Resistance
- Low time constant
- High specific power and energy
- Wide temperature range (-55˚C-125˚C with some to 200˚C)
- Fast recharge time
- Unlimited Cycle Life
- Unlimited Shelf Life
- High Reliability

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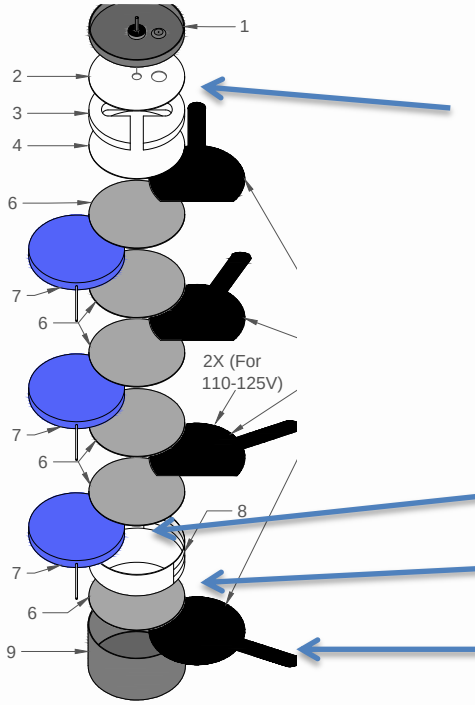
HYBRID CAPACITOR CONFIGURATION Phase 1 - THQ

THQ3



PTFE Insulator(s)

TaO5 Anode(s)

Separator(s)

RuO2 Cathode deposited on Ta Foil

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HYBRID CAPACITOR DEVELOPING Higher Power Phase 2

Phase 2 – Increase cap without adding to height or footprint

THQ SERIES
CUSTOMER REQUIRED MORE POWER, BUT OFFERED NO ADDITIONAL SPACE

THS SERIES: BY FILLING IN THE CORNERS WE WERE ABLE TO OFFER 1/3 MORE CAPACITANCE IN THE SAME FOOTPRINT

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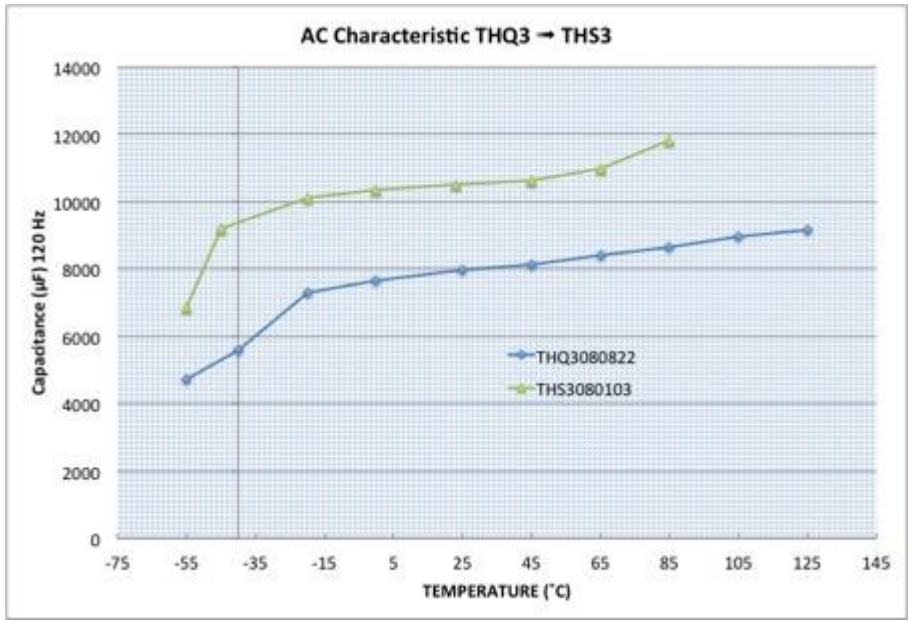
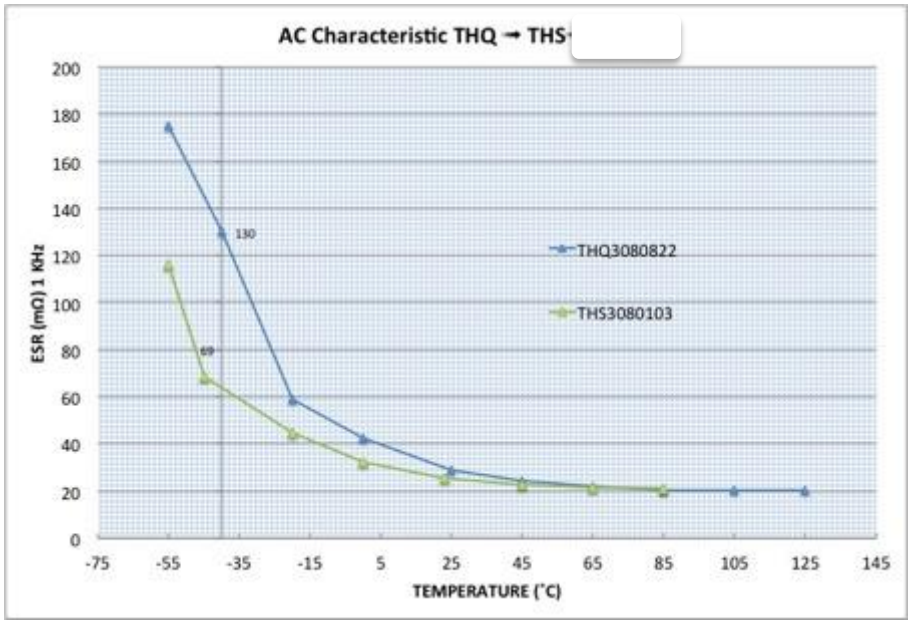
HYBRID CAPACITOR CUSTOMER DRIVEN DESIGN

Phase 1 – AC Results





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HYBRID CAPACITOR DEVELOPING Higher Power Phase 3

Phase 3 – REDUCE ESR

THS SERIES:
80V 10mF 40mΩ max
Customer needed lower resistance to reduce cooling requirements during high power duty cycling.

TDD SERIES:
80V 9mF 18mΩ max
A COMBINATION OF IMPROVENTS AND DIRECT CUSTOMER INPUT LEAD US TO THE “DAVE’S DREAM”

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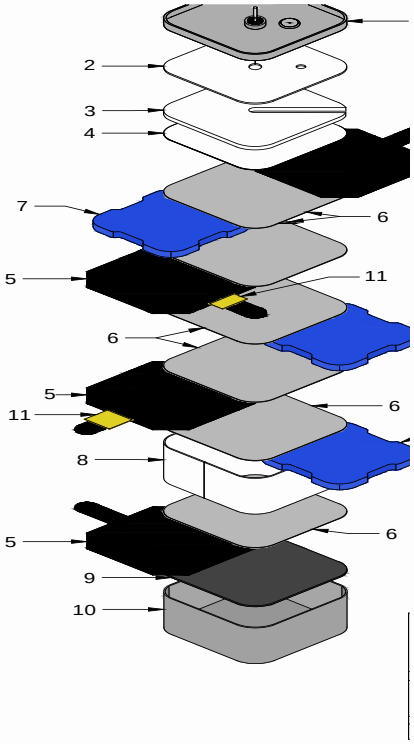
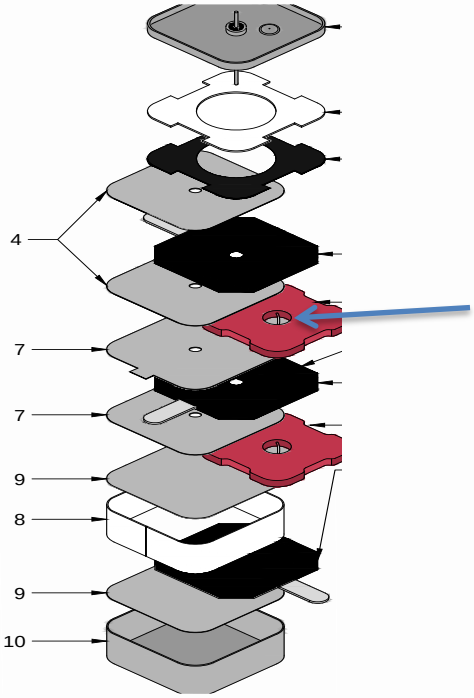
THS / TDD CAPACITOR CONFIGURATION



THS3



TDD2

(+) connection

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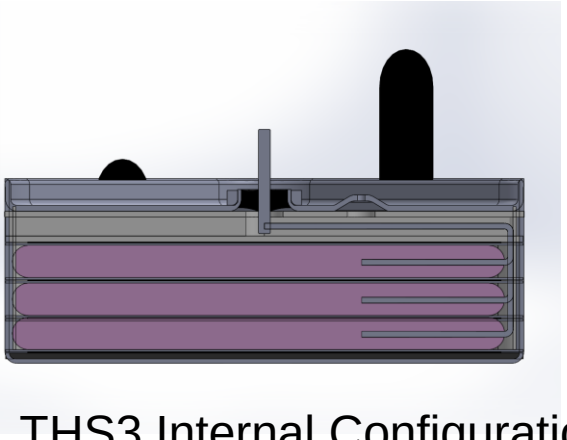
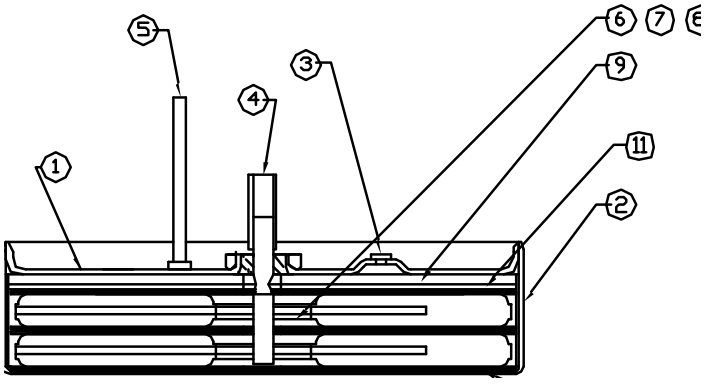
THS / TDD CAPACITOR CONFIGURATION



THS3 Internal Configuration



TDD2 Internal Configuration

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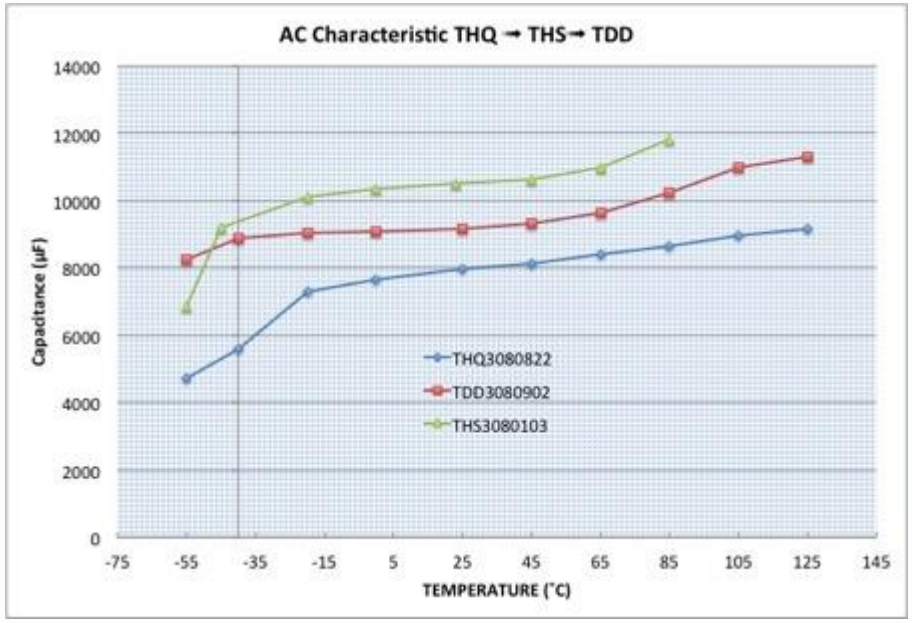
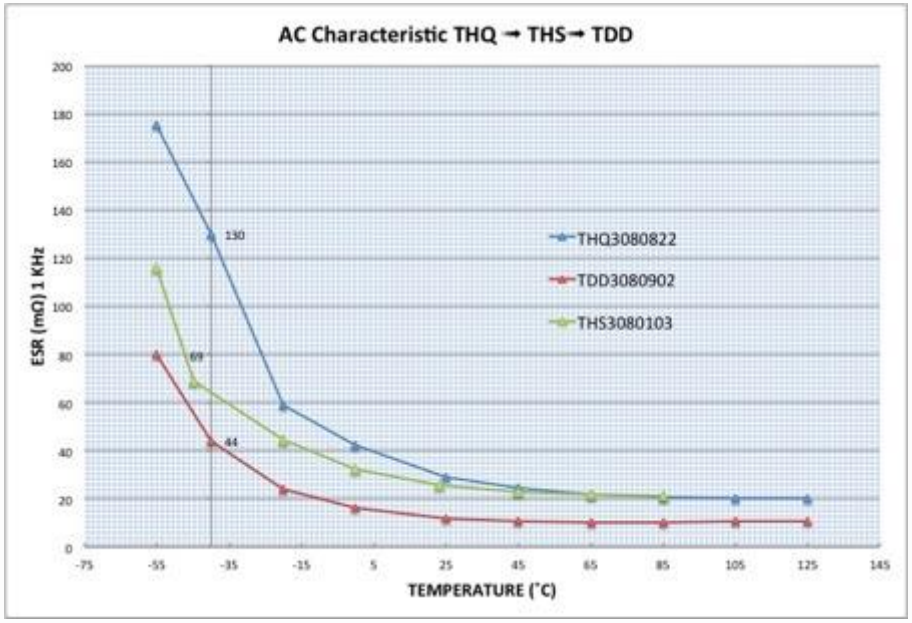
HYBRID CAPACITOR CUSTOMER DRIVEN DESIGN

Phase 2 – AC Results





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HYBRID CAPACITOR RELIABILITY

- Life is > 2,000 Hrs at Rated Voltage & 85˚C
- Life is > 2,000 Hrs at 60% Rated Voltage & 125˚C
- MTBF > 5,000,000 Hrs - High current pulse power (qualification test for E2D)
- MTBF > 30,000,000 Hrs – in service life on Apache Arrowhead
- TDD Cycle test for LLNL – 6 Billion Cycles over 231 days
- TDD Radar Qualification >3,000hrs with temp cycles, at full power
- Over 400,000 Hybrid Capacitor units sold since 2001
- Routinely specified, screened and qualified for space applications
  - Incorporating EEE-INST-002 guidlines

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HYBRID CAPACITOR RELIABILITY

Flight Qualification TDD2

3000 to 5000 hrs

Temp cycling environment

35 Amp pulse

Duty cycle > 10%

500 to 1,000 Hz

Expected to be end of life

PDA revealed pristine components

No age related deterioration

RMA	Part #	T (C)	Technician	Date	Time
120616-RTH	TDD2080602[redacted]	24	PP	1/25/17	6:53 AM

428267 is from Inventory

AS SHIPPED

Serial	Cap. (uF)	ESR (mOhms)	5 min. DCL - 80v	HGT	Lot #	Date Tested
237615	6542	16.62	23	NA	1207C	2/20/12
237631	6236	17.04	26	NA	1207C	2/20/12
239197	6301	15.63	47	NA	1209G	3/5/12
239202	6153	16.59	35	NA	1209G	3/5/12
428267	6180	15.23	22	NA	1627AB	7/25/16

AS RECEIVED 1/25/17

Serial	Cap. (uF)	ESR (mOhms)	5 min. DCL - 80v	HGT	Lot #	Date Tested
237615	6461	15.60	85	0.4656	1207C	1/25/17
237631	6164	15.73	83	0.4696	1207C	1/25/17
239197	6100	15.64	84	0.4629	1209G	1/25/17
239202	6129	15.88	130	0.4633	1209G	1/25/17
428267	6015	15.74	48	0.4679	1627AB	1/25/17

Diff. Serial	Cap. (uF)	ESR (mOhms)	5 min. DCL - 80v		Swell Across	Swell Diag.
237615	-81	-1.02	62		0.0095	0.0111
237631	-72	-1.31	57		0.0086	0.0158
239197	-201	0.01	37		0.0068	0.0110
239202	-24	-0.71	95		0.0090	0.0055
428267	-165	0.51	26		0.0102	0.0113

POST RECONDITIONING 1-27-17

Serial	Cap. (uF)	ESR (mOhms)	5 min. DCL - 80v	HGT	Lot #	Date Tested
237615	6538	15.56	25	0.4660	1207C	1/27/17
237631	6293	16.15	31	0.4700	1207C	1/27/17
239197	6237	15.91	32	0.4635	1209G	1/27/17
239202	6251	15.79	29	0.4625	1209G	1/27/17
428267	6127	15.61	33	0.4676	1627AB	1/27/17

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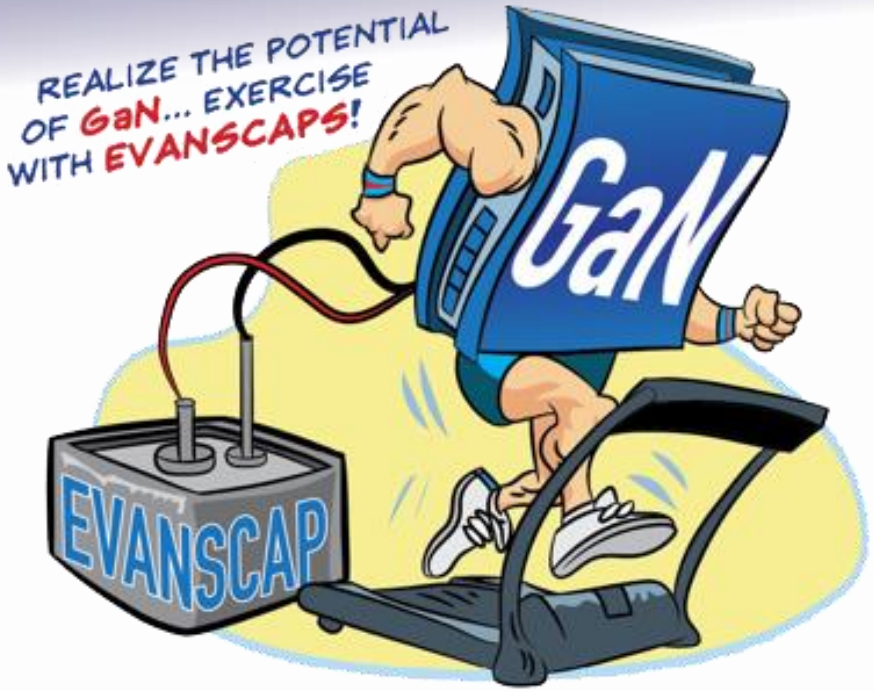
80V 6,000µF
< 0.027Ω 13cc 86g

Pictured: TDD2080602SM01



- **Highest Power Density**
  Large Capacitance
- **Very High Current Handling**
- **Unlimited Shelf Life**
- **Unlimited Cycles**
- **Most Efficient**
  Very Low ESR (even at low temp)
- **Fully Hermetic**
- **Excellent Heat Transfer**
- **High Reliability**

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