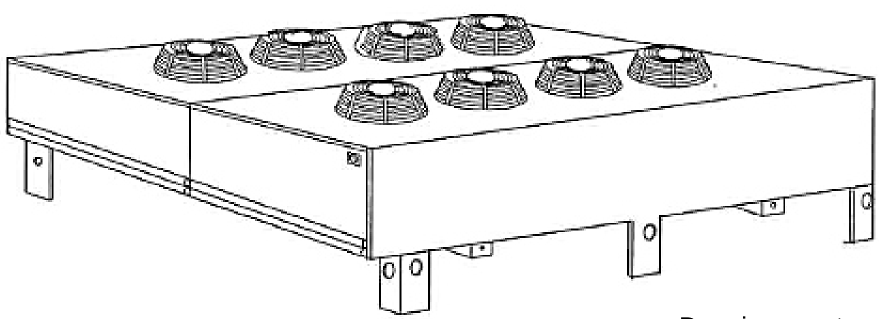
# Application Note
# CTAN #344

**The Application Note is pertinent to our AC Drive Families**

## Single Drive Running Multiple Motors

Running multiple motors simultaneously with a single drive is an economical method of controlling motors that are designed to be running at *approximately* [1] the same speed in a particular machine. One such application is in the manufacture of fiber. Often those machines run a multitude of spindles all winding up thread in unison. Often in these cases the motors being run are fractional HP where having a singular drive for each motor would be cost prohibitive and add additional coordination complexity.

Another common application where a single drive is applied to the job of running multiple motors is for cooling fans on chilled air condenser heat exchange units similar to the array as shown below.



Drawing courtesy of Liebert Corp
Divison of Emerson Electric

[1] When running Open Loop ( without an actual motor shaft speed sensing device ), motor speeds will vary depending on individual loads variations.

Typically the VFD will be set up to run in a purely Open Loop mode- specifically in the V/Hz mode. More exotic modes such as the Open Loop vector are of little use as these modes tend to optimize motor speed control by using a more exact model of the motor by determining the motor characteristic following an auto tuning procedure. Obviously, running an autotune on a multi-motor setup would tend to confuse and distort the model of what the drive would think is a specific "single motor". The V/Hz mode does not attempt such modeling and subsequent runtime adaptations therefore provides a constant basis for all motors connected in parallel.

However, connecting all motors in parallel presents other engineering considerations. All the extra wiring means extra losses. Resistive losses which result in a voltage drop from the drive to the motors but an even greater concern with this extra wiring is the extra capacitive losses between motor leads and earth. Plus one needs to consider the extra capacitive losses within the motors themselves ( stator to frame, stator to rotor, rotor to frame via bearings) as these tend to sum as well. All these extra losses results in a loss of current that actually makes it to the motors.

Another consideration is motor protection. In single motor applications the drive offers Ixt ( Current over Time ) Overload protection against allowing the motor to draw currents in excess of its' FLA rating. In multiple motor applications, the drive has no way of knowing how much any one motor is demanding, therefore it is unable to offer the same kind of motor overload protection. In such applications, individual external overload devices are employed.

Besides these considerations, when confronted with the application of using a single drive to run multiple motors, there are a couple of fundamental questions that one needs to ask right up front:

***Are all motors always going to be started together ?*** As opposed to: "*Sometimes a motor is to start later and join the rest of a group that had already been started."*

***Are all motors going to stop together ?*** As opposed to: *"Sometimes a motor is turned off independent of others still running".* Such "Load Dumping" can result in nuisance drives trips if the drive is too small to absorb this shock and must also be considered.

***Are all motors clustered together ?*** As opposed to being scattered about. This has ramifications on wiring lengths and overall general system layout.

**YES-Let's call this the Normal Case**

If the answers to these 3 questions are YES then this falls into the more standard and simple case.

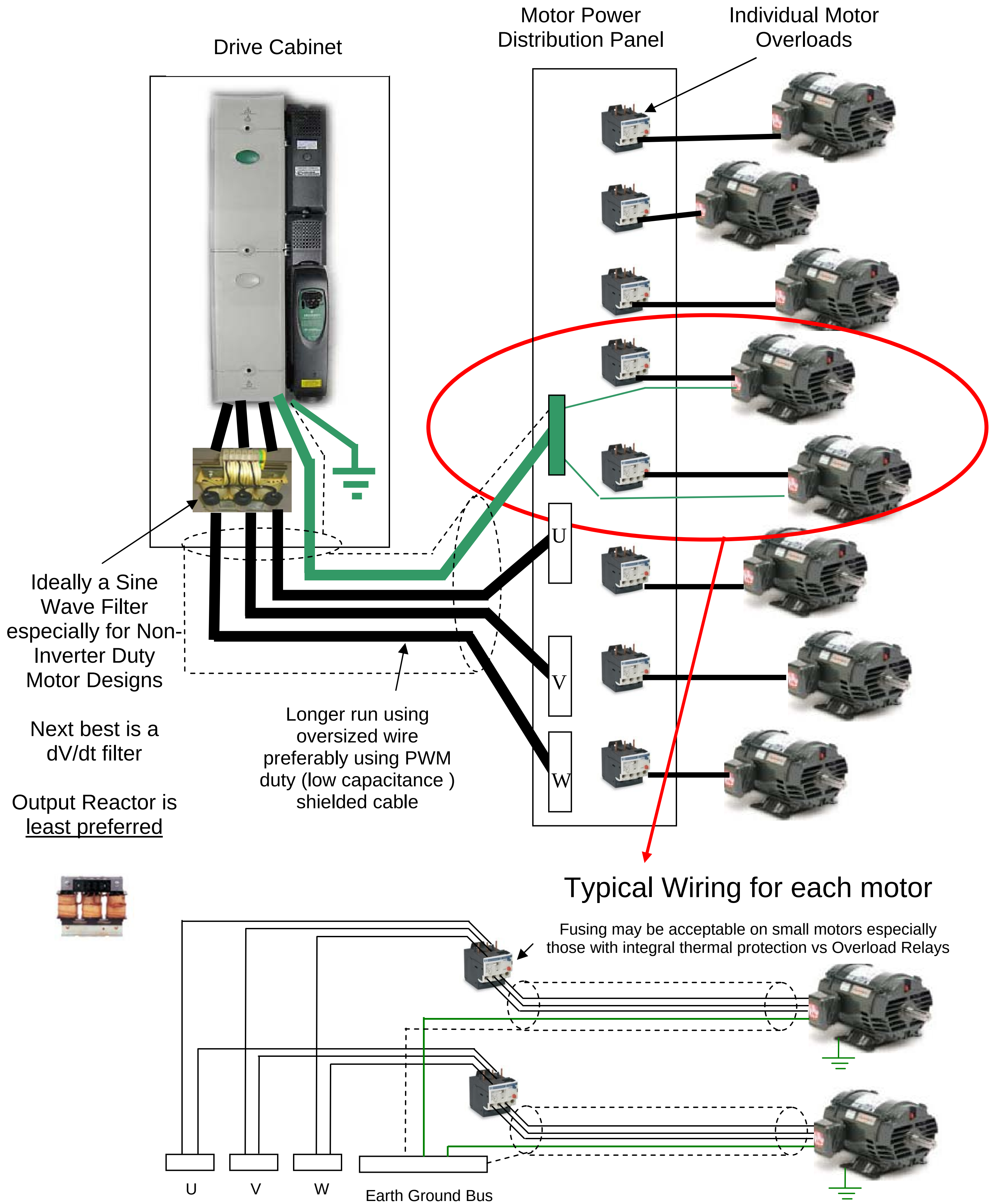
In this case, a drive must be selected based on the expected total motor FLA ( full load amps ) PLUS some extra margin to account for the additional distributed capacitive and resistive wiring losses.

The reason that this case is more simple is that since all motors start together, one doesn't need to be concerned about the high starting current ( 5-6x FLA) requirement of a motor being dropped across the drives output when already up to frequency supplying other motors. In addition, since all motors stop together we don't have to be concerned with "load dumping" effects- the effect of a sudden drop in load when disconnecting a running motor from the drives output- not to mention having to deal with the complexities of the inductive arc in the associated switch gear- selection of an appropriately rated motor starter.

## **Normal Case Example**

Suppose you need to run eight 10 HP 460vac motors and these motors need to operate in unison. The motors are identical and the nameplate indicates a FLA of 15.2A running a variable torque application.

First of all we need a drive that can provide in excess of 8 x 15.2A or 122A. For 8 motors we might want to assess another 20-25% to account for overall losses depending on the general layout as discussed previously. Therefore we want to specify a drive that can deliver at least 145A or so. The SK5402 can provide 156A.


Drive Cabinet
Motor Power
Distribution Panel
Individual Motor
Overloads
Ideally a Sine
Wave Filter
especially for Non-
Inverter Duty
Motor Designs
Next best is a
dV/dt filter
Output Reactor is
least preferred
U
V
W
Longer run using
oversized wire
preferably using PWM
duty (low capacitance )
shielded cable
Typical Wiring for each motor
Fusing may be acceptable on small motors especially
those with integral thermal protection vs Overload Relays
U
V
W
Earth Ground Bus

## Practicalities

One should always use Inverter duty motors rated for use with contemporary IGBT PWM drives. But this is not always possible. Existing applications arise that involve non-inverter duty motors. In these cases, one should employ a **Sinewave Filter**.

The ideal case, when multiple motors are being driven from a single drive, would be to utilize a Sinewave filter on the drive output regardless whether the motors are inverter duty or not. This will turn the PWM output waveform into a nearly pure sinusoidal waveform that minimizes cable and motor capacitive losses and virtually eliminates the propensity to cause insulation breakdown in non-inverter duty motors. See following page

If one uses a sinewave filter, the use of costly oversized shielded motor cable could most likely be avoided.

There have been numerous cases where a simple output reactor was used with non-inverter duty motors and insulation damage occurred. For that matter, there have been cases where even when a dV/dt Filter was used with non-inverter duty motors and insulation "punch thru" damage still occurred.

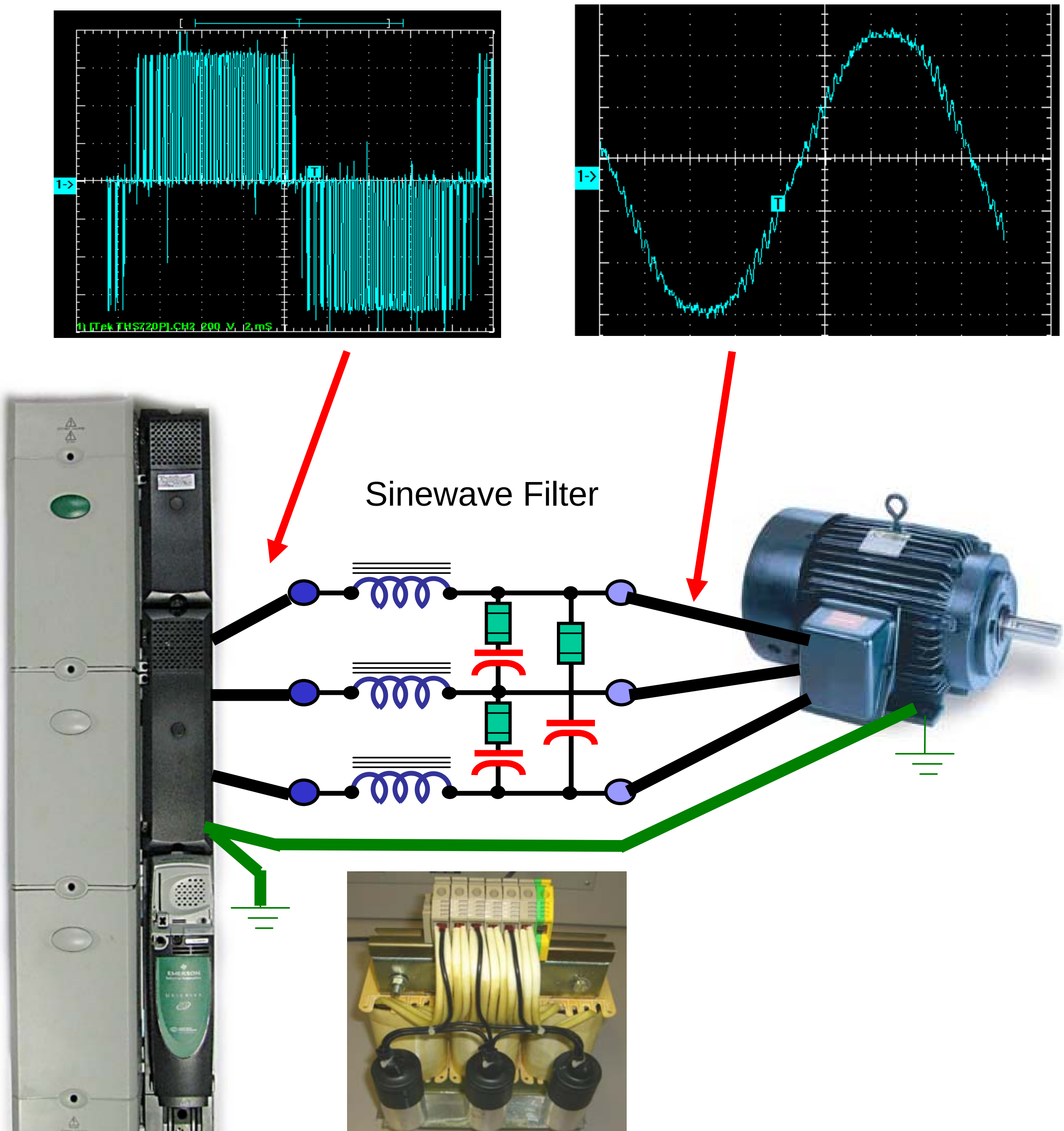
If the motors are Inverter duty rated, often one can get by using a simple, lower cost output line reactor and in combination with oversized low capacitance cabling, to minimize losses. Low capacitance cabling rated for PWM drives can be expensive when employing larger motors. In these cases the compromise solution may be using a dV/dt filter and regular motor cabling ( again oversized to account for long distance resistive losses and voltage drops).

Just using an output reactor without low capacitance cabling is the worst case as for losses. There have been cases where the drive was outputting full current when measured using an AC clamp-on on the drive output terminals yet the motor failed to turn. Moving the AC clamp-on to the motor end of the cable one measured only 60% of that current measured at the drive.

One must not under estimate the effect of capacitive losses in the motor cabling to the conduit and between motor leads themselves. In addition, the cumulative summation of the internal capacitive losses of all the motor stray capacitance between the stator and the motor frame plus rotor to frame via the bearing race can be considerable especially at higher carrier/switching frequencies. The higher the carrier the greater the losses.

Then of course, there is the loss across the output device itself whether it be an Output Reactor, dV/dt or Sinewave Filter. When selecting a filter make sure you specify the maximum desired switching frequency you plan on using.

# Application of Sinewave Filter




Sinewave Filter

# <u>Other Considerations</u>- Motor Overload Protection

Other considerations might include:

***What happens if a Motor Overload trips ?   How will one know ?***

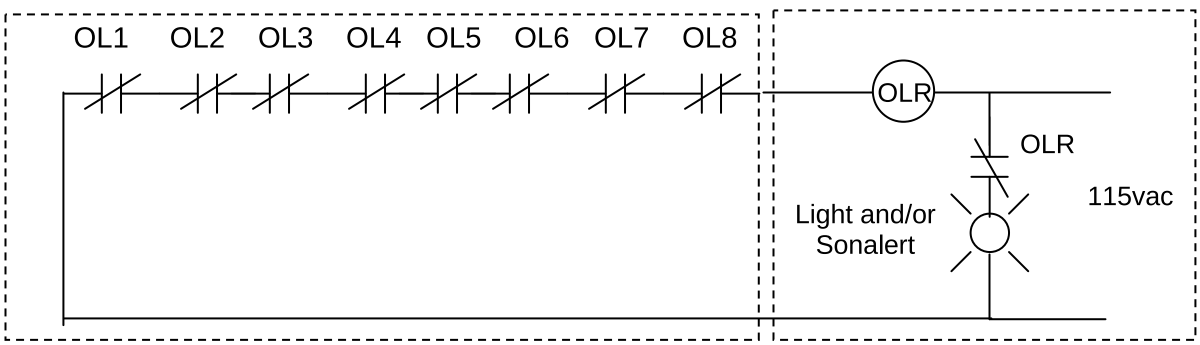
Obviously, you would need to specify an Overload unit that offers a contact that changes state when tripped.

If these contacts are NC ( normally closed ) and opens upon a trip condition, one would wire all the overload auxiliary contacts in series so that if any one Overload trips, it would break the series string back to the drive cabinet.

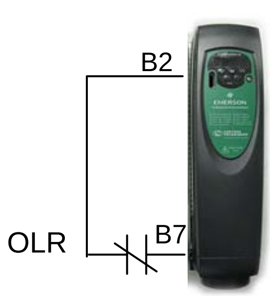
***But what do you do with this fact and how do you get it to the drive ?***

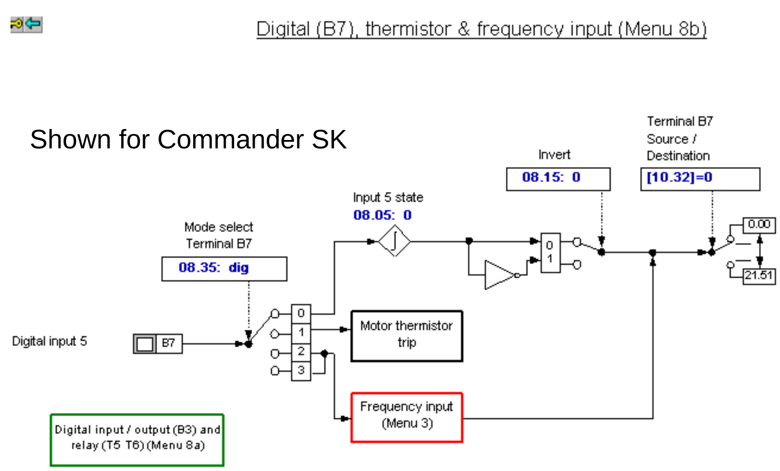
Well, what you don't want to do is to run these wires from that string back thru the same conduit with the noisy motor power leads then directly into the drive. What you would like to do is operate a relay located in the drive cabinet which would isolate this overload contact string from the drive.

**Located in Motor Power Distribution Cabinet** **Located in Drive Cabinet**




If you wish to trip the drive if one of the motor overloads trip, you could do the following: the Drive will annunciate with Et External Trip




**<u>Note</u>**: This OLR contact must be a completely separate (dry ) contact not associated with the 115vac !!!

## Other Considerations- Motor Thermostats

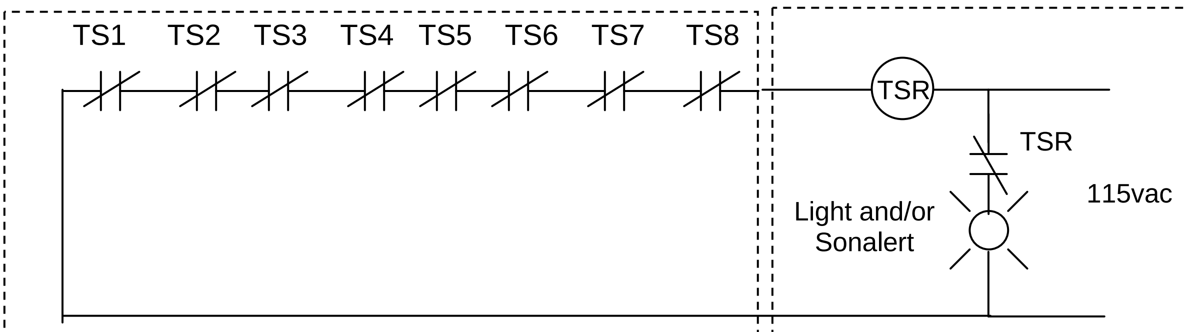
Motors often contain an internal thermostat embedded within the motor in close proximity to the stator winding. This thermostat is typically a NC ( normally closed ) contact that opens at an elevated temperature. This change of contact state is used to signal a motor controlling device that the motor is running hot so that appropriate action can take place.

One would wire all the thermostats in series so that if any one of the thermostats opens, this series string would be broken.

***But what do you do with this fact and how do you get it to the drive ?***

Well, what you don't want to do is to run these wires from the series string back thru the same conduit with the noisy motor power leads then directly into the drive. What you would like to do is operate a relay located in the drive cabinet which would isolate this thermostat contact string from the drive.

**Located in Motor Power Distribution Cabinet** **Located in Drive Cabinet**

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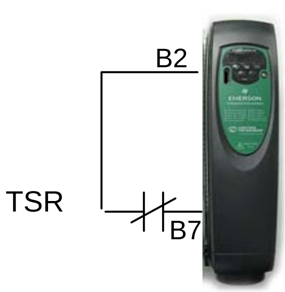
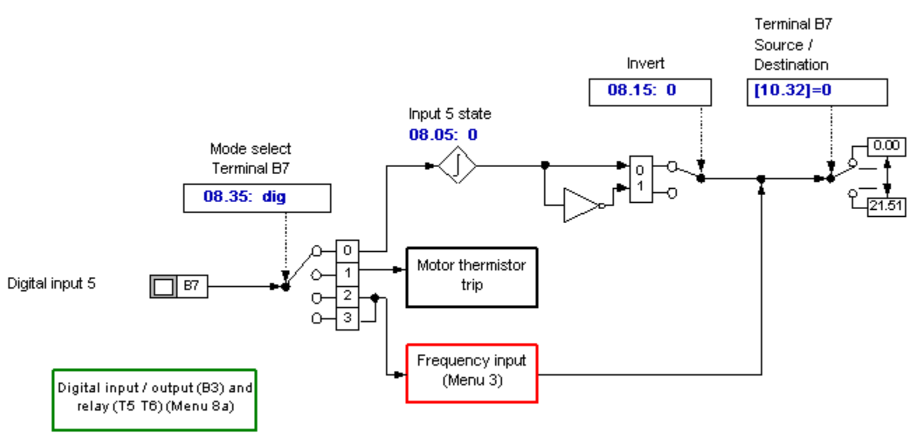
Digital (B7), thermistor & frequency input (Menu 8b)




Shown for Commander SK




**Note**: This TSR contact must be a completely separate (dry ) contact not associated with the 115vac !!!

## Other Considerations- Motor Thermostats & Overloads

***What if you have both Motor Overloads and Thermostats ?***

Well, you would merely put both strings in series.

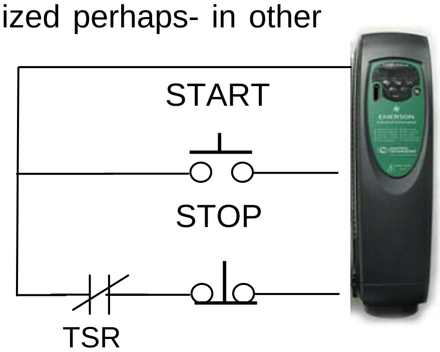
## Other Thoughts

In both previously mentioned cases the end result of either an Overload or Thermostat contact opening will trip the drive with Et if programmed so.

However, these are two different situations. In the case of the Overload trip, that particular motor will typically be disconnected from the drive. This happens automatically via the Overload contactor. In this case, the machine may not be able to run correctly without all motors running so tripping the drive might be acceptable.

Certainly in the case of a Thermostat opening, a motor has become Hot but this does may not warrant rudely tripping the drive ? Will the motor become immediately cooler if we trip the drive immediately ? Or would it be nicer to merely Ramp Stop the drive so that all motors come to a controlled stop in a timely coordinated manner, then annunciate the trip and prevent re-starting until the motor is cool once again. Some manufacturing processes would appreciate the later case whereby material scrap would be minimized perhaps- in other cases it may not matter.

To accomplish this, one would merely put a NC contact from the TSR (**T**hermo**S**tat ) **R**elay in series with the NC Stop button assuming the drive uses a 3 wire Start/Stop circuit.




You would **not** want to place this contact in series with a Run contact from a Control System however.

**Run**- From Controller


**Note**: This TSR contact must be a completely separate (dry ) contact not associated with the 115vac !!!

Obviously, should a Thermostat trip, the drive would drop out of run **BUT** as soon as the motor cooled down the drive would re-start at that time which may not be a safe condition. In these cases, it would be best that the controller be cognizant of the Thermostat state(s) and handle the RUN command appropriately.

In many cases one may not want to trip the drive should a particular motor complain of overtemperature. One may merely want to shed that motor and continue on. In those cases it is always best to ramp the drive down to zero speed, drop the complaining drives contactor, possibly pick up another motor in its' place and re-start the drive.

## More Complex Cases

These involve situations where the motors do not all start or stop together. In general we would prefer to say "Don't Do It"- use individual drives. This application can be troublesome depending on the size of the drive vs the motor being line started. If the motor(s) being line started are small relative to the drive size, then this would be a much better situation and you would have a better chance of overall success. ( See next page for an alternative solution ). But if you insist - you may have an application where the motors are all different sizes. For example, let's say there is an application where there is a 40HP and 10HP and 3- 2HP , 460vac motors that are to be run from a single drive.

| | |
|---|---|
| **40HP** | **55A** |
| **10HP** | **15A** |
| **2HP** | **3.7A** |

Obviously , the worst case would be if the application required starting of the 40HP after the other motors were up to speed/load- ( the switchgear to handle this is another matter –see Motor Starters ). You would need to account for the starting current requirement which is essentially the LRA ( locked rotor amps) of that motor being line started. If that is not readily available, a rough estimate would be 5-6x the FLA ( full load amps). This would required a "line starting" current of at least 275A ( 5x FLA ) plus the amount of current for the other motors – so you would need a drive that can provide 300A peak current at the very least. Depending on the load and motor type the starting current may be 6x rated or requiring a drive that could supply 350A peak and this doesn't take into account temperature or additional margin for cable, filter and other associated losses. Don't skimp when it comes to this kind of situation- this kind of impulse shock load can cause a drive to trip out on an Instantaneous Over Current Trip very easily if there isn't sufficient headroom.

However, when one examines the cost of the above application, the cost of a drive that can provide 350A peak, it would become rather obvious that the use of individual drives would be a better overall solution.

With the same motor line-up, the best case in this kind of scenario would be that they only line start the 2HP motors and even at that, not at the same time. In this case, we would need

55A +15A + 7.4A + 5(3.7A)= 96A then say 10-15% for losses say
a drive that can provide at least 110 A peak

## An Alternative Solution

What if the application is such that by nature not all motors are required all the time.  For instance,  in some blower cooling applications only 1 fan may be required to keep the equipment cool enough.  But should that fan not be able to keep the equipment cool enough there would be a need to bring another motor on-line.  The problem is always “Line Starting” and “Load Dumping”.

When the assistance of another motor is required (or no longer needed ) a technique that could be applied would be to simply take the speed of the running motor(s) to zero and close ( or open ) a motor contactor to add in ( or shed ) another motor to the system.  After that contactor is verified closed the drive could be re-started and ramped up to speed.

In this manner,  high Line Starting currents or Load Dumping negative effects are avoided.

# Other Notes

## Wiring

Always segregate power cable from signal wiring.

- Segregate any wires that run with the motor wires ( Thermostat and/or Overload wiring ) as these will contain a high content of PWM noise specifically when shielded motor cable is not being used.

- The OLR and TSR relays shown on previous pages could be powered by a +24vdc supply vs 115vac but should NOT be the +24vdc supplied by the drive. This would be an invitation to bring potentially disturbing electrical noise into the drive system since it would be associated with a long distance run to/from the remote mounted motors.

## Drive Setup ( Driving Multiple Motors )

- Set the drive Voltage Mode to a V/Hz mode. Fixed Boost ( Fd ) or Square Law (SrE) are acceptable for multi-motor applications.

- Slip Compensation should be turned off or disabled. This can be accomplished by setting #5.27=0 or setting the rated motor rpm equal to the synchronous speed ie

  1800 rpm for a 4 pole machine
  3600 rpm for a 2 pole machine
  1200 rpm for a 6 pole machine

- Don’t attempt running autotune – static nor dynamic.

- Use S-Ramp accel/decel – no need for linear ramps in most any application. Turn on #2.06 and set #2.07 to about ½ - ¾ or the accel (#0.03) value.

- Coast Stop could be used but you will need to wait until motors coast to a stop before attempting a re-start. Catch a Spinning motor would have a difficult time with this application since an autotune was unable to be performed- ( technically required for Catch a Spinning motor to work properly). So we would not recommend reliance on this feature.

## Summary

From a technical point of view, when running multiple motors from one drive there are a number of thing to consider:

1. The size of the drive is determined by the total full load amps (FLA) of all the motors connected to the drive at one time ( plus extra to cover losses )
2. The individual motors must have their own individual motor overload protection. The drive can really only be set-up to provide overload protection if only one motor is connected to it.
3. Short circuit protection for the individual motor wiring may be required if there is either more than two equally sized motors or if there is a large difference in HP of two motors connected to the same drive.
4. The individual motor overload protection needs to be supplied either by the drive manufacturer or by the integrator. This can be in the form of individual motor overloads, overloads internal to the motors, or motor circuit protectors (MCPs) which can provide both overload protection and short circuit protection.
5. Short circuit protection (if required) can be supplied by either individual branch circuit protection in the form of fusing or with motor circuit protectors.
6. Although individual motors can be disconnected from the drive while the drive is running, adding them back to a running drive may result in tripping of the drive unless the drive is significantly oversized. In general, this practice should be avoided.

**Additional considerations:**

- Connecting multiple motors in parallel can result in cable lengths that exceed the limits of the VFD. It may be necessary to output conditioning devices to reduce cable losses.
- If individual motors have to be switch on while the VFD is active, over sizing of the VFD is required.
- Can the motors really be run up and down together or would it be better to have individual drives for individual motors?
- Does the economics of this make sense? Wiring all the motors back to one drive may be more costly than wiring them to individual drives. Supplying a large enclosure with multiple motor overloads and fusing or motor circuit protectors may be more costly than individual drives.
- What happens if for whatever reason the drive fails? Would I be better off with more than one drive?
- From economic and operational viewpoints, would two drives each with their own motor be more advantageous than a single drive running two motors?

- What happens if one of the motors becomes overloaded and shuts down the drive? Can I disconnect that motor and continue to operate or would I be better off with more drives?

# Conclusion

A single drive running multiple motors can be an economical approach for certain applications. As can be seen there are some considerations depending on system layout, motor ratings, cable and PWM filtering methods. The sizing of the drive and protection of both the motors and wiring between the motors are issues which must be analyzed. One should be cognizant however, should this single drive fail, the entire application will be down- as opposed to using a drive for each motor whereby that motor section could possibly be bypassed and the remainder of the machine system may still be usable. For this reason, one should always keep a spare for single drive, multi-motor system.

# **Other Resources**

## **Shielded Cable for VFD's**

**http://www.houwire.com/products/belden.asp**

**http://canada.newark.com/pdfs/techarticles/belden/EVFDCP.pdf**

**http://www.servicewire.com/products/vfd_armor.html**

**http://www.servicewire.com/products/vfd_tray.html**

## **Filters**

**Sinewave**

**dV/dt Type**

**Output Line Reactor**

**Questions ?? Ask the Author**:

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