

FIELD ANALYSIS OF A THREE PHASE MODULAR DOUBLE SALIENT LINEAR MOTOR BY MEANS OF FEM

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ABSTRACT

The finite elements method (FEM) lends itself to a wide range of disciplines, as structural analysis or electromagnetics. The MagNet program package based on this method was used to analyse the magnetic field of a three phase modular double salient linear motor. This linear motor is one of the best choices for industrial applications where fast and accurate linear motion under heavy loads are required. All the obtained results are in good accordance with the theoretical expectations and with the results of analytical computations.

1. INTRODUCTION

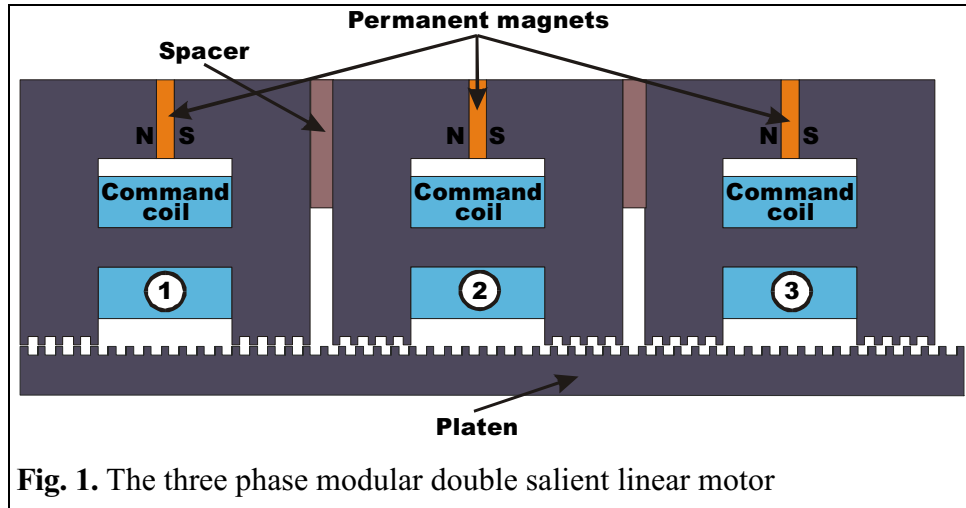
The finite element method (FEM) is a numerical method for solving a system of governing equations over the domain of a physical system. The concept of the finite element analysis (FEA) has been in use in some form for centuries. The simple idea is to replace a complex problem with a simpler one, that represents the true solution to a desirable degree of accuracy. It is apparent that ancient mathematicians employed finite element (FE) like problem solving techniques to many physical problems. With the advent of the computer FEA can now be applied to more broad and sophisticated problems [1].

There are several commercially available FEM based programs for the analysis of electromagnetic devices in two or three dimensions, like ANSYS, FLUX2D, FLUX3D, MagNet, etc. All these are reliable, efficient and user-friendly CAD software packages. There are very useful in the design and analysis of magnetic equipment and devices with linear, nonlinear and permanent magnet materials.

The MagNet 6.10 package was used to analyse the magnetic field in a three phase modular double salient linear motor.

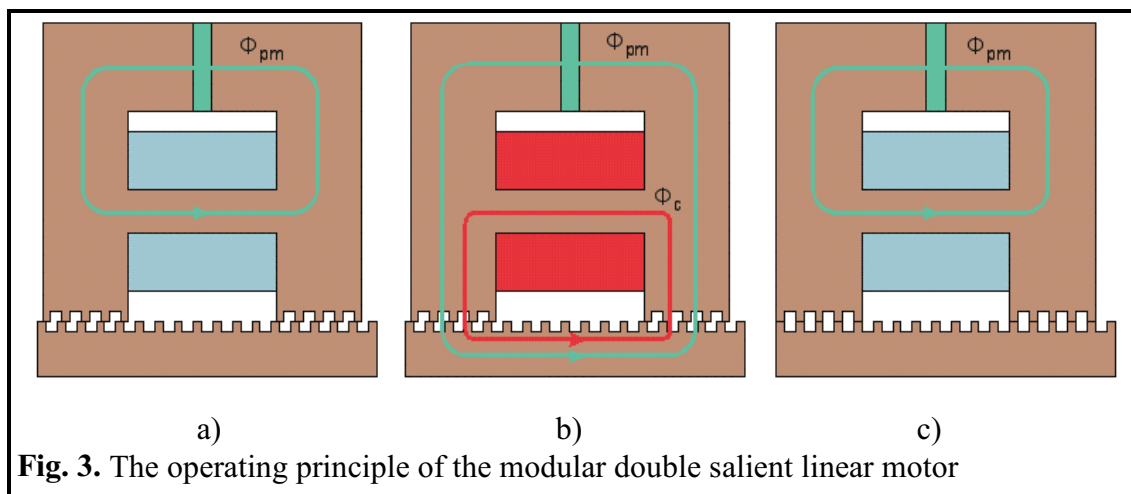
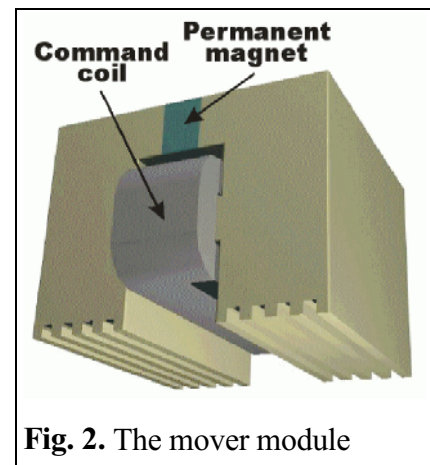
2. THE THREE PHASE MODULAR DOUBLE SALIENT LINEAR MOTOR

The three phase modular double salient linear motor is a direct-drive linear motor, which can replace ballscrews, gear trains, belts, and pulleys, all of these being limiting factors for engineers trying to improve the linear drive system's performance. Therefore this motor is simple, efficient and has high positioning accuracy. The acceleration available from this motor is especially remarkable compared to traditional motor drives, which convert rotary motion to linear motion. Therefore these motors are ideal for applications that require high position accuracy and repeatability.



The motor, shown in Fig. 1, has essentially the same construction as a classical linear switched reluctance machine [2], with the single difference that it has high-energy magnets placed in the mover.

The moveable armature is a single stack composed of three modules (like that presented in Fig. 2) [3]. Each module has a rare earth permanent magnet, two salient teathed poles and a command coil. The toothed structure is the same on the mover's poles and on the platen. If the command coil is not energised, Fig. 3a, the magnetic flux generated by the permanent magnet, Φ_{pm} , passes through the core branch parallel to the permanent magnet due to its smaller magnetic resistance. In this case there is no significant force produced. If the coil is energised, Fig. 3b, the command flux produced by it, Φ_c , directs the flux of the permanent magnet to pass through the air-gap and to produce significant forces. Due to the force the mover moves one step to minimise the air-gap magnetic energy, Fig. 3c.



The tooth pitch and the number of modules determine the motor's resolution. By advanced control strategies the resolution of positioning can be increased significantly.

The motor offers particularly strong benefits in applications where fast and accurate moves under heavy loads are required (flexible manufacturing systems, robotic systems, machine tools, conveying systems, linear accelerators, turntable drives, automated warehousing etc.).

The main dimensions (in millimetres) of the analysed sample modular double salient linear motor's mover module are presented in Fig 4.

The most significant characteristics of the sample motor are given in Table I.

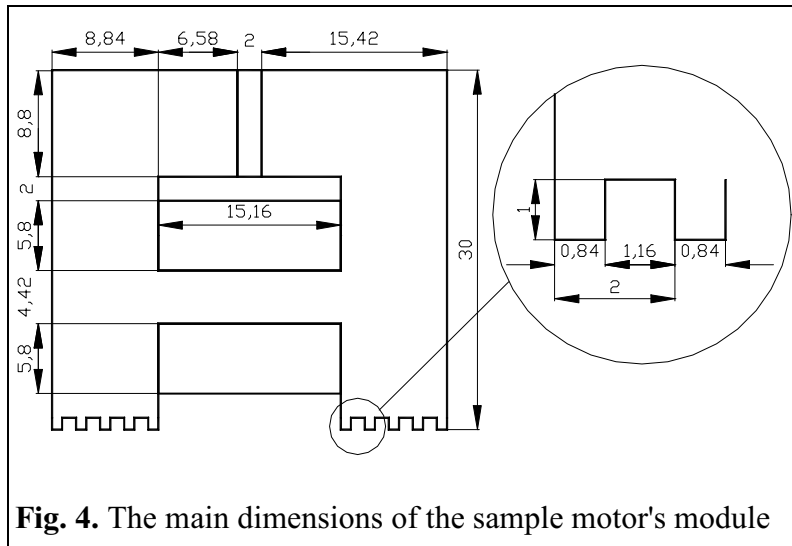


Fig. 4. The main dimensions of the sample motor's module

Table I.

Number of modules	3
Number of teeth per pole	5
Tooth width	0.84 mm
Slot width	1.16 mm
Tooth pitch	2 mm
Number of turns	400
Rated command current	1 A
Nominal tangential force	150 N
Motor width	83 mm
Air-gap	0.1 mm

3. NUMERIC FIELD ANALYSIS OF THE THREE PHASE MODULAR DOUBLE SALIENT LINEAR MOTOR

The numeric field analysis of the three phase modular double salient linear motor was performed by the FEM based

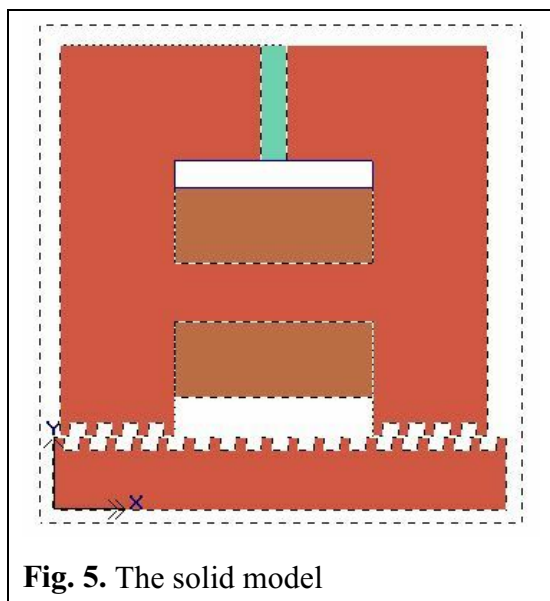


Fig. 5. The solid model

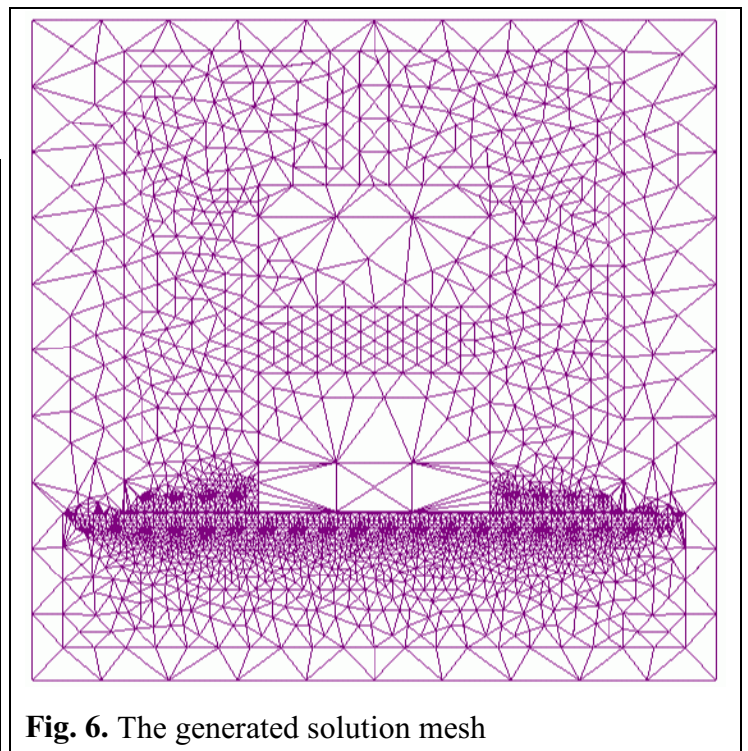
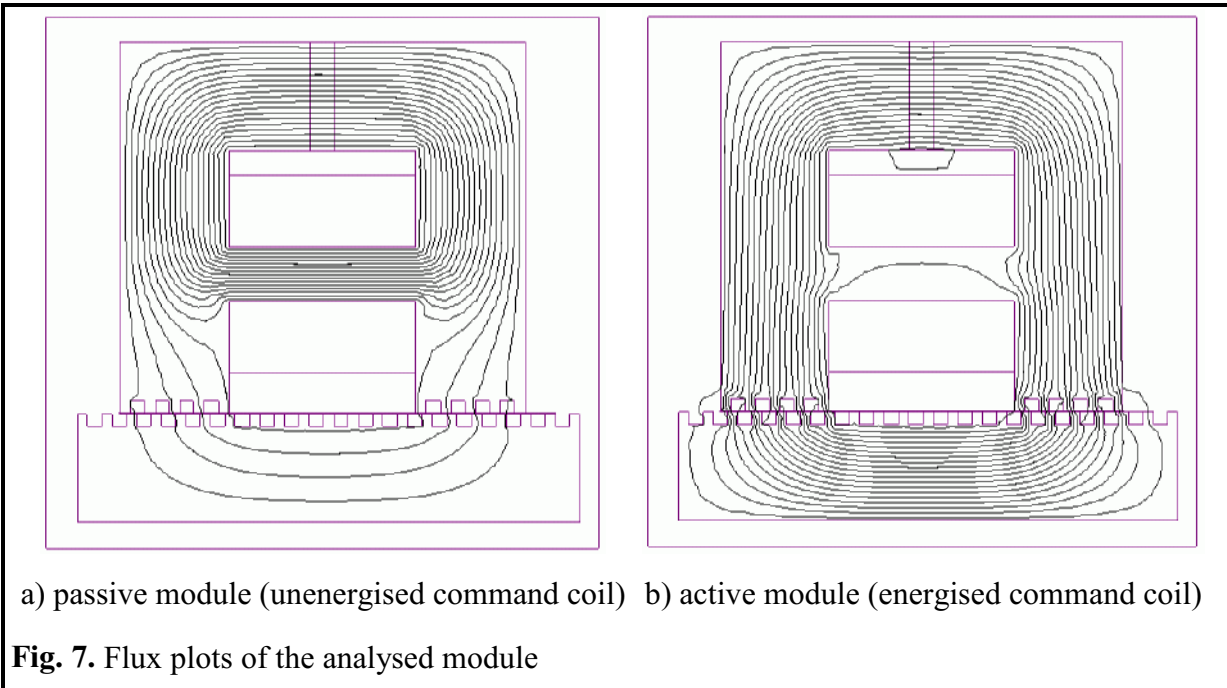


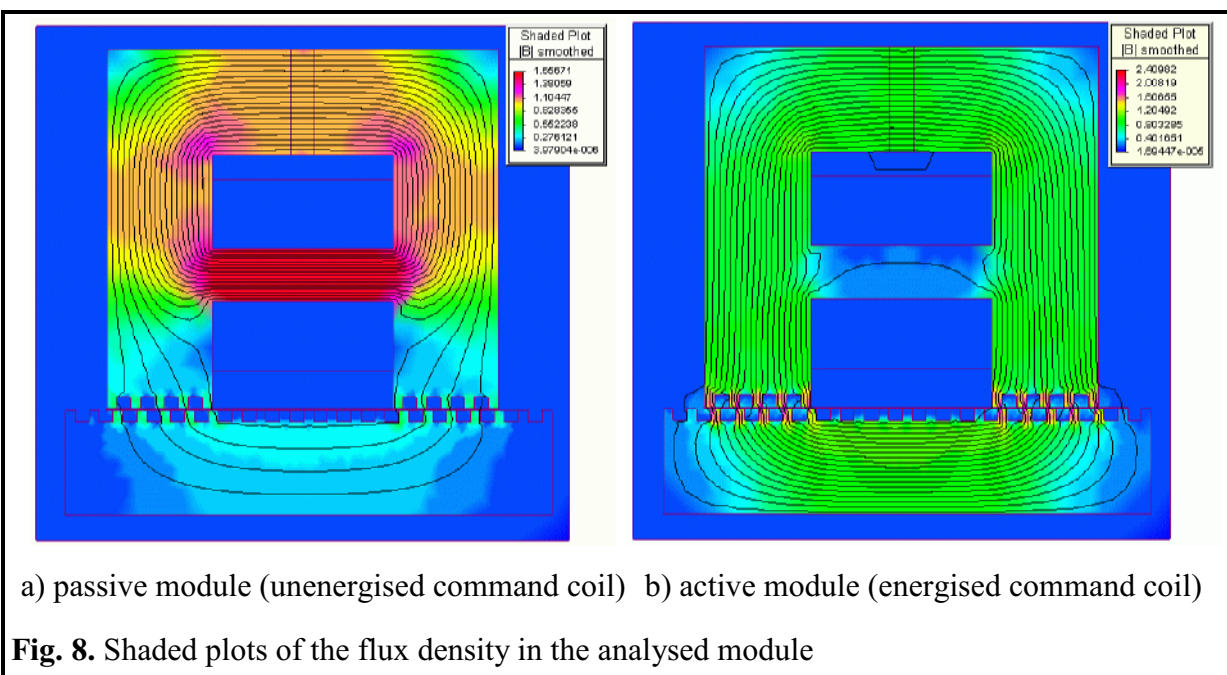
Fig. 6. The generated solution mesh

MagNet 6.10 package [4]. First only a single module with the platen part above it was analysed. Its solid model and the solution mesh generated by the program are shown in figures 5 and 6.

In Fig. 7 the obtained flux plots are presented for a passive, respectively active module. The module is in a relative position of $x=0.5$ mm. The command coil is fed by 1 A current. As it can be seen, the obtained results are perfectly in accordance with the theoretical expectations.



There is possible to represent the flux density distribution in the studied domain by using shaded plots. The magnitude of the flux density in each motor part can be determined by using the attached color maps. The shaded plots of flux density for the passive, respectively active module are given in Fig. 8.



Using the program package the tangential (F_t) and normal components (F_n) of the developed forces can be easily computed. The results of the force computations are included in Table II.

Table II.

	Tangential force [N]	Normal force [N]
Passive module	7,828	38,393
Active module	131,245	520,814

In the next step the numeric magnetic field analysis was performed for the entire motor structure. Of course the number of the generated elements (see Fig. 9 with the solution mesh of this problem) is about three times greater, therefore the computation time is also longer.

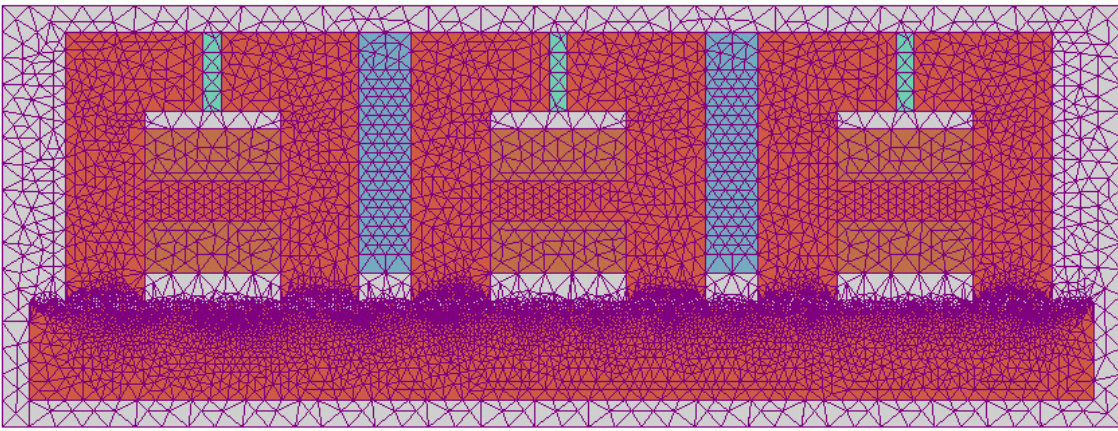


Fig. 9. The solution mesh for the entire motor structure

In Figs. 10 and 11 the flux plots for are shown for the initial position of the mover ($x=0$ mm) and in it final position after one step displacement ($x=0,66$ mm). During the movement the command coil from the middle of the mover is fed with a command current of 1 A.

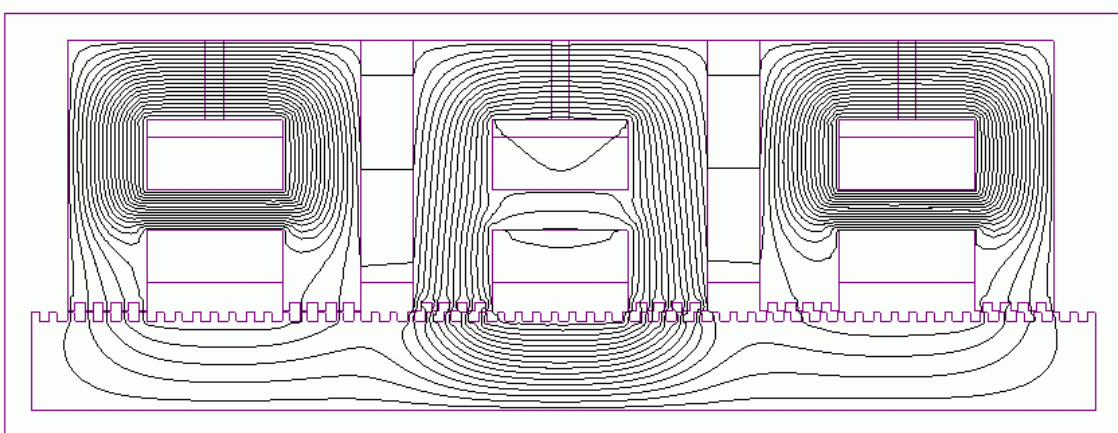


Fig. 10. The flux plot of the motor structure at the beginning of the movement

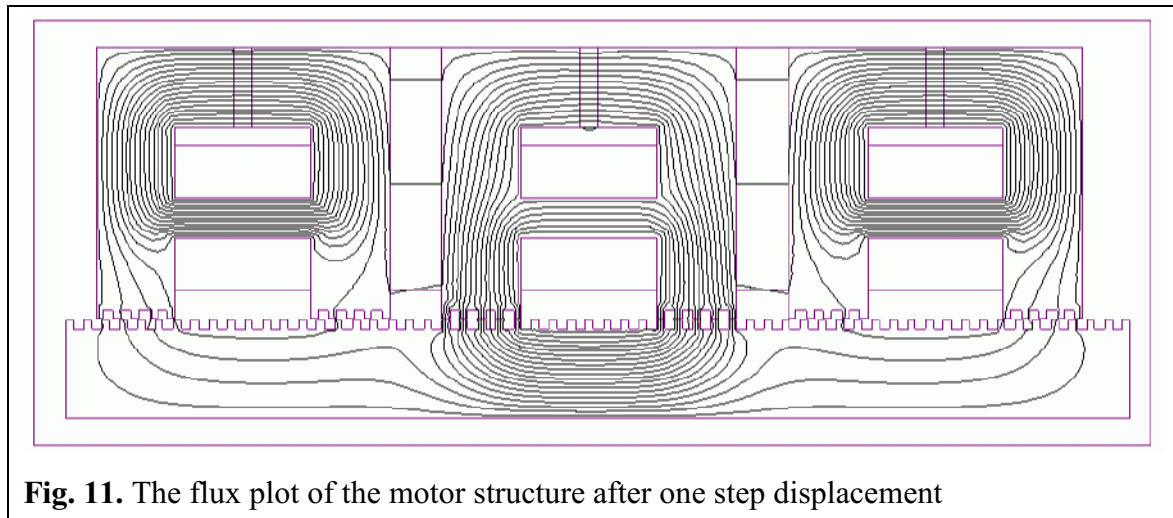


Fig. 11. The flux plot of the motor structure after one step displacement

As it can be seen in the last two figures, 10 and 11, the command flux produced by the coil directs the flux of the permanent magnet to pass through the air-gap. In the final position of the mover, due to the reduced air-gap permeance for the aligned position of the teeth, the command flux not only directs the flux of the permanent magnet, but also generates force. For this reason for an optimal control the command coil must be energised in a manner to only direct the permanent magnet flux.

Finally it can be concluded, that all the obtained results are in good accordance with the theoretical expectations and with the results of former analytical computations.

4. ACKNOWLEDGEMENT

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5. REFERENCES

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